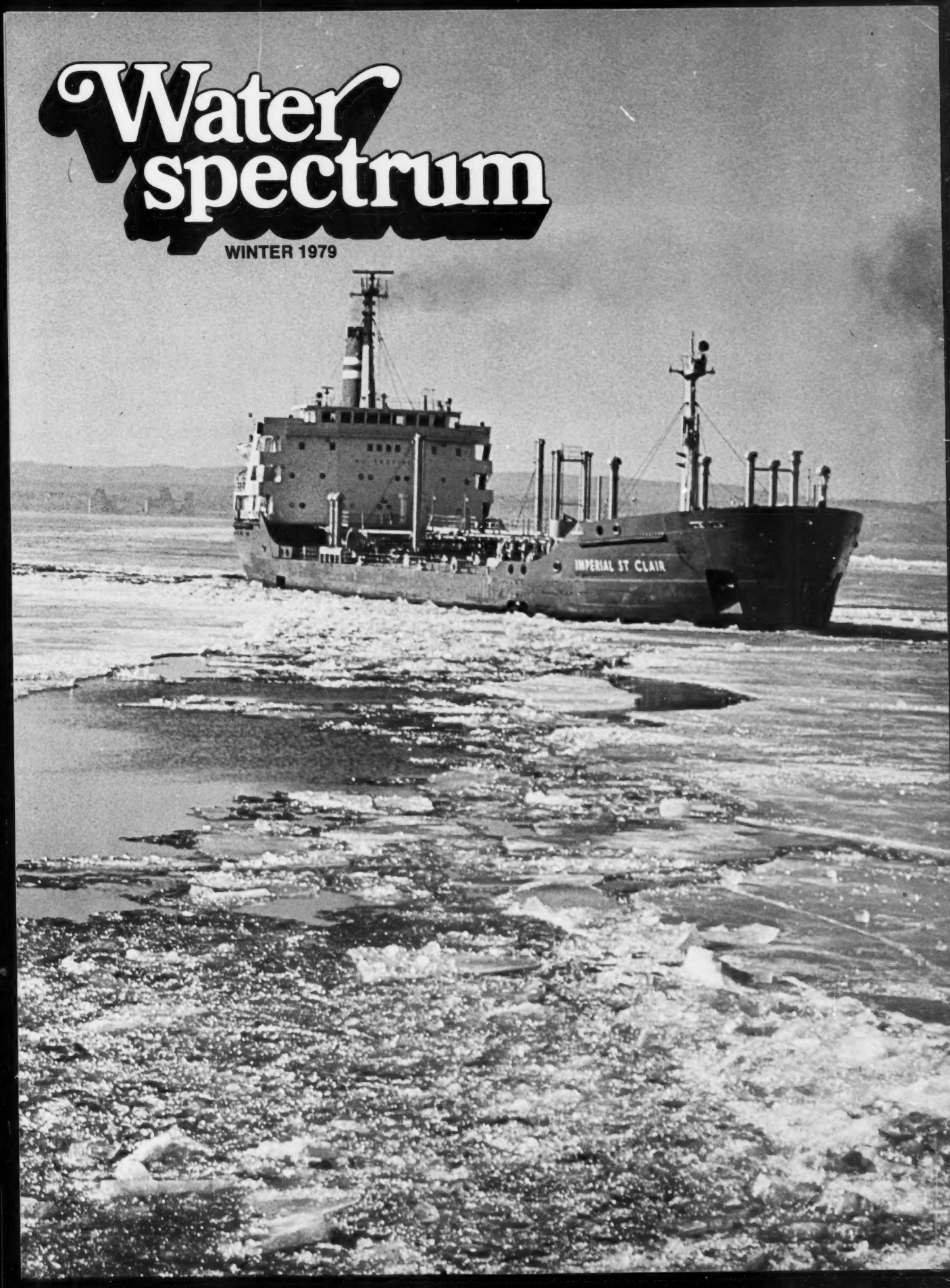
Water spectrum

WINTER 1979



Water spectrum

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COVER: Is it time for a "breakthrough" in the perennial ice closure of the Great Lakes? See Page 35.

Getting On With The Job

By **Charles Warren**

On December 7, 1970, the Corps of Engineers filed a final environmental impact statement (EIS) for a flood control project on the Cache River in Arkansas. At the time, the National Environmental Policy Act (NEPA), which requires EISs for major federal projects significantly affecting the quality of the human environment, was less than a year old. The Cache River EIS, one of the Corps' first, consisted of seven pages.

In September of the following year the Corps circulated for comment the draft of a plan, intended as an amendment to the EIS, to mitigate losses to fish and wildlife habitat should additional funding be provided. However, several conservation groups, state, and private individuals filed legal objections charging that the initial EIS was inadequate and, in subsequent court proceedings, citing comments critical of the EIS and the mitigation plan from the Department of the Interior's Fish and Wildlife Service and the Environmental Protection Agency, respectively. A federal district court ruled against the plaintiffs in April 1972 but they appealed.

On September 25, 1972, the Corps filed a larger revised EIS which included the final version of the mitigation plan. In December a federal appeals court reversed the lower court decision, rejected the initial EIS as inadequate, and sent the case back to the district court.

In March 1973, the district court ordered the Corps to produce a new EIS, and on November 8, 1974, the Corps filed the statement—its third version for this project—over 375 pages long, plus four additional volumes of comments and responses, appendices, mitigation plan, and litigation documents. After more litigation, in 1976 the district court found the revised EIS legally adequate. Finally, in late 1977,

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Mr. Warren is Chairman of the Council on Environmental Quality.

. . . Almost seven years after the filing of the initial EIS . . . the project was legally ready to proceed.

Recent Cache River floods have created scenes such as these at Grubbs (right) and Daggett, Arkansas (below).
(Memphis District, CofE Photos)

almost seven years after the filing of the initial EIS, a federal appeals court affirmed the district court's decision. Finally the Cache River Project could go ahead.

This Project, located in northeastern Arkansas, would enlarge and realign about 230 miles of channel in the Cache River and certain tributaries, including Bayou DeView, in order to promote drainage and reduce flooding in about 790,000 acres of bottomlands. By protecting the land from frequent flooding, the project as originally designed would have accelerated the clearing and draining, for the purpose of soybean farming, of at least 110,000 privately-owned acres of one of the last remaining southern flood plain forests in Arkansas.

The Fish and Wildlife Service objected to the project on the grounds that it would destroy excellent fish and waterfowl habitat, including much of the most important wintering area in North America for several hundred thousand mallards and other ducks. Also, it questioned the adequacy of the mitigation plan, which at the time called for the purchase and preservation of 30,000 acres of forest (now authorized to include up to 70,000 acres within the limits of a cost ceiling of $7 million). The Environmental Protection Agency also had doubts about the mitigation plan and expressed concern about the effect of the project on water quality downstream. Meanwhile, during the protracted litigation over the EIS, the value of soybeans rose rapidly, encouraging landowners to clear more of the forest to create farmland. In addition, some landowners may be seeking to prevent the government's purchase of their property as mitigation land. Thus, the long delay due to litigation over the EIS has had some of the same adverse effects expected of the project itself.

While the Corps was preparing its first EIS in 1970, several federal and state agencies and environmental organizations proposed either alternatives to channelization or other modifications of the project, but the Corps failed to discuss them sufficiently. Indeed, in rejecting the statement, the Eighth Circuit Court of Appeals stated that the Corps "most

"... a concern with quality, not quantity."

significant failure" was its "unsatisfactory discussion of alternatives to channelizing the Cache River." The court also ruled that the Corps had to consider mitigation features as part of the EIS, even if they would have to be funded separately.

Some critics of "environmentalism" in general, and of the EIS process in particular, may regard the doleful history of the Cache River project as a typical example of obstructionism based on a piece of paper. Actually, the Cache River case is unusual: of the tens of thousands of federal actions reviewed for environmental impact *each year,* and of the 7,334 projects for which EISs were filed between January 1, 1970, and June 30, 1976, only 783 were challenged in court on NEPA grounds. In those six and-a-half years, only 177 projects were postponed by a court injunction, and only 75 were delayed for more than a year.

The Cache River project is not a good example of the EIS process; on the contrary, it is one of the more memorably bad examples. However, it does illustrate some of the reasons for occasional long delays under NEPA in the past—and—perhaps more important—it can illustrate how the new NEPA regulations proposed by the Council on Environmental Quality (CEQ) can help avoid delays of even short duration in the future.

When NEPA went on the statute books in 1970, the Council on Environmental Quality (created by the same law) was ordered to oversee the EIS process. Since, at the time, no agency including CEQ knew precisely what such an animal was, what it should look like, or (perhaps most pertinent in light of subsequent experience) what it should weigh, the Council developed "Guidelines" to help agencies prepare impact statements.

These Guidelines were an excellent start toward defining the proper content of what was then an unfamiliar document. But the authority of the Guidelines was ambiguous: were federal agencies *required* to follow them, or were they purely advisory? Some courts held them to be legally binding, while others treated them as helpful hints which an agency could adopt or disregard; as it chose.

'. . . Decision-makers must consider the alternatives described in the EIS.

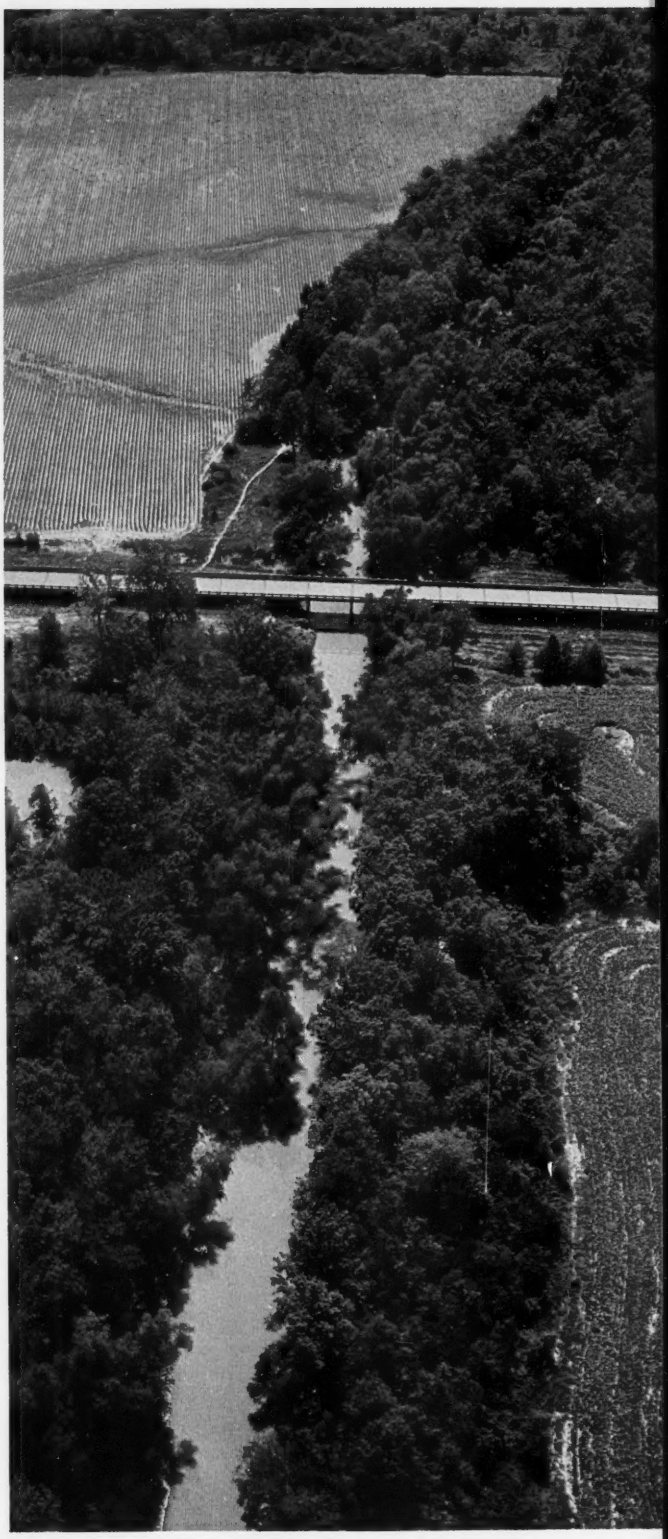
This ambiguity about the force of the Guidelines contributed to a number of problems for which the EIS process became unfairly but undeniably infamous:

- It led to constant squabbles in and out of court over what an "adequate" EIS was. This occurred because, in deciding NEPA-based suits, some courts gave those Guidelines great weight, while others accorded them less authority. Some project managers and their government lawyers, in an effort to anticipate every possible challenge, produced massive EISs that buried critical issues in mind-boggling heaps of barely pertinent ecological data.
- Because of varying agency attitudes toward the Guidelines, the scope and content of EISs differed from agency to agency; this lack of uniformity bewildered and angered private applicants who dealt with more than one federal agency.
- In cases (such as Cache River) where disputes arose among agencies, the Guidelines provided for refereeing by CEQ—but no clear authority to compel such arbitration. Therefore interagency disputes could become interminable.
- Perhaps most important, too often there were inconsistent interpretations of the Guidelines from agency to agency.

Taken together, these and other deficiencies resulted in the generation of excessive paperwork, unnecessary delays, and duplications of effort.

In his Environmental Message of May 23, 1977, President Carter stated that NEPA has had "a dramatic—and beneficial—influence on the way new projects are planned." But, he continued, "to be more useful to decision-makers and the public, environmental impact statements must be concise, readable, and based upon competent professional analysis. They must reflect a concern with quality, not quantity. We do not want impact statements that are measured by the inch or weighed by the pound."

Accordingly, the President directed CEQ to develop legally binding regulations to meet the criteria of true usefulness and quality, and "to establish a procedure for referring



The Cache River Basin Project will provide flood protection for 790,000 acres of agricultural land and several rural communities in central Arkansas. (Memphis District, CofE Photos)

132 miles of the Cache River would remain in their natural state.

to the Council differences among agencies" regarding the implementation of NEPA.

The following month, CEQ held public hearings at which we were careful to enlist the view of NEPA critics as well as those of supporters. Presentations by business and industry, for example, were coordinated for us by the U.S. Chamber of Commerce, and labor union testimony by the Building and Construction Trades Department of the AFL-CIO. Altogether, more than 300 individuals and organizations from government, industry, labor, the academic community, and environmentalist organizations testified. Interestingly, despite many criticism, not a single witness advocated the repeal or serious weakening of NEPA and its EIS requirement.

Over succeeding months, CEQ sifted the recommendations from the public and reviewed numerous internal CEQ and other federal agency analyses of NEPA. We incorporated what seemed to be sound suggestions into a proposed set of formal regulations and circulated a draft document to those who had testified as well as to all federal agencies. They offered new suggestions, and CEQ made further revisions. On June 9, 1978, CEQ published its proposed regulations in the Federal Register for formal public review and comment. The comment period extended for 60 days. The new regulations were to be issued in final form sometime last fall.

What's In Them?

The regulations run to 17 pages in the Federal Register, so I obviously cannot cover everything here. But I can cite some of the most important provisions, and then suggest how the regulations might have speeded resolution of the problems with the Cache River project.

Highlights of the new regulations might be classified under three headings: reducing paperwork, reducing delay, and better decision-making.

Reducing Paperwork

CEQ recommends that the EIS will normally be less than 150 pages, and no more than 300 pages for projects of "unusual scope or complexity." The new regulations specify that EISs should be analytic rather than encyclopedic, zeroing in on significant environmental issues and deemphasizing those of lesser importance; thus the number of issues treated in an EIS will be narrowed.

The statements must be written "in plain language" and follow a standard format, from cover sheet to appendices—thus simplifying their use by decision-makers and the public. Agencies are authorized, under the new regulations, to adopt adequate EISs of sister agencies when such statements already exist, and to combine documents prepared under NEPA with other agency documents to reduce duplication and paperwork.

Reducing Delay

One of the most important innovations in the new regulations is called "scoping"—a process designed to help an agency define, at the start of its environmental review, the content of an EIS. Through meetings or any other appropriate form, agencies must consult with affected state and local governments, and with proponents as well as opponents of a proposal, to identify the key issues and alternatives to be addressed in the EIS.

Joint preparation of EISs by federal, state, and local agencies is permitted by the regulations to avoid generating several documents where one would suffice. For projects involving more than one federal agency, the regulations establish procedures for determining which agency shall have primary repsonsibility for EIS preparation. In the event of interagency dispute, CEQ can designate this "lead" agency.

The new regulations establish criteria for setting time limits on completion of the NEPA process. If a private applicant involved in the process requests such a deadline, the agency must set one.

Many types of federal actions do not require EISs. Rather than deciding these on a case-by-case basis, agencies will—under the new regulations—be able to define as "categorical exclusions" those actions that do not normally require detailed environmental analysis.

Channelization of some 230 miles of the Cache, including enlargement and realignment, is anticipated in northeastern Arkansas.

Improved Decision-making

To focus the NEPA process on real options, the EIS *must* present the range of alternatives under actual consideration, must evaluate each alternative in sufficient detail to permit a proper comparison of alternatives, and must identify the best alternative(s) from an environmental point of view. Decisionmakers *must* consider the alternatives described in the EIS.

Decision-makers are not required to choose the most environmentally favorable alternative. If they do not, however, they must explain their reason for not doing so in a brief record summarizing their choice among courses of action.

A critical element in the approval of many actions has been agreement by the sponsoring agency to adopt measures to mitigate environmental damage. In the past, however, there has been no mechanism to follow up on an agency's mitigation measures. The new regulations require agencies to implement the measures agreed to during the EIS process, to monitor their own efforts in important cases, and to provide such monitoring data on request.

How might these regulations have speeded work on the Cache River project?

Under the new regulations, these events would have taken place:

- First, as a result of the required "scoping" process, the Corps would have had to include in its first EIS alternatives and mitigatory measures proposed by Fish and Wildlife and other critics of the Cache River proposal. The Corps reaction to those alternatives and measures is beside the point; it would have been *required* to place them in a document open to the public. At a bare minimum, compliance with the scoping process would have gone far toward ensuring that the first EIS would have been adequate in content.
- Second, the Corps would have been explicitly required to explore and objectively evaluate all reasonable alternatives to channelization with the same detail and thoroughness it accorded its preferred course of action. Simply put, it would have had to take the alternatives seriously rather than—as was the case—dismissing them. It would have been required to explain, if it rejected the alternatives, why it rejected them.
- Third, if differences still persisted between the course advocated by the Corps and that suggested by other federal agencies, the project proposal would have been referred to CEQ for arbitration.

The new regulations do not promise sweet harmony; disputes among agencies, and between agencies and the public, will persist. But they do guarantee that project sponsors and opponents will have to focus beforehand on the major issues dividing them, and that the EIS will consider those issues with an analytic thoroughness that permits fair comparison and prudent choice.

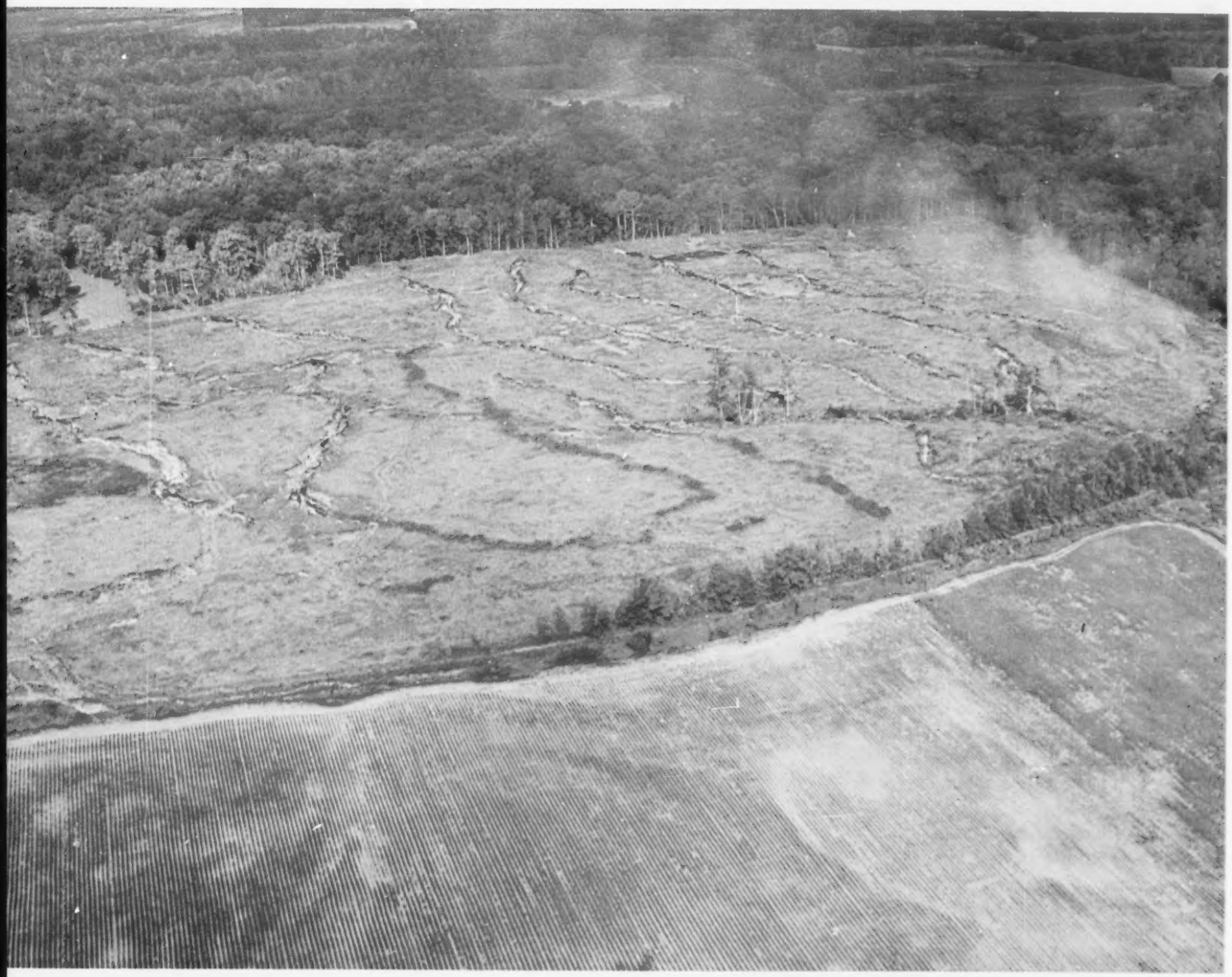
The Cache River project is used only as an illustration of the potential of the new regulations. A similar story could be told for many other controversial federal projects. The Cache River project may in fact have a happy ending, because the Corps, the Environmental Protection Agency, and the Interior Department are now engaged, at long last, in a mutual review and evaluation of project alternatives which could resolve their concerns. We believe that the proposed regulations can greatly accelerate the resolution of such conflicts.

Further, we believe that the new regulations will reduce even further the relatively small number of EISs that are challenged in court. Project sponsors who comply with the new NEPA regulations have no guarantee that a dam, highway, or license will not be challenged following completion of an EIS. Yet any agency which can prove that it did its best to satisfy the requirements of the new regulations will, judging by the record, find the court on its side. It will probably have CEQ in its corner too.

Most importantly, the new regulations aim not at a better piece of paperwork, but at better federal actions. They will enable every agency to speed its compliance with the National Environmental Policy Act, and thus get on with the job the American people have comissioned them to do. ■

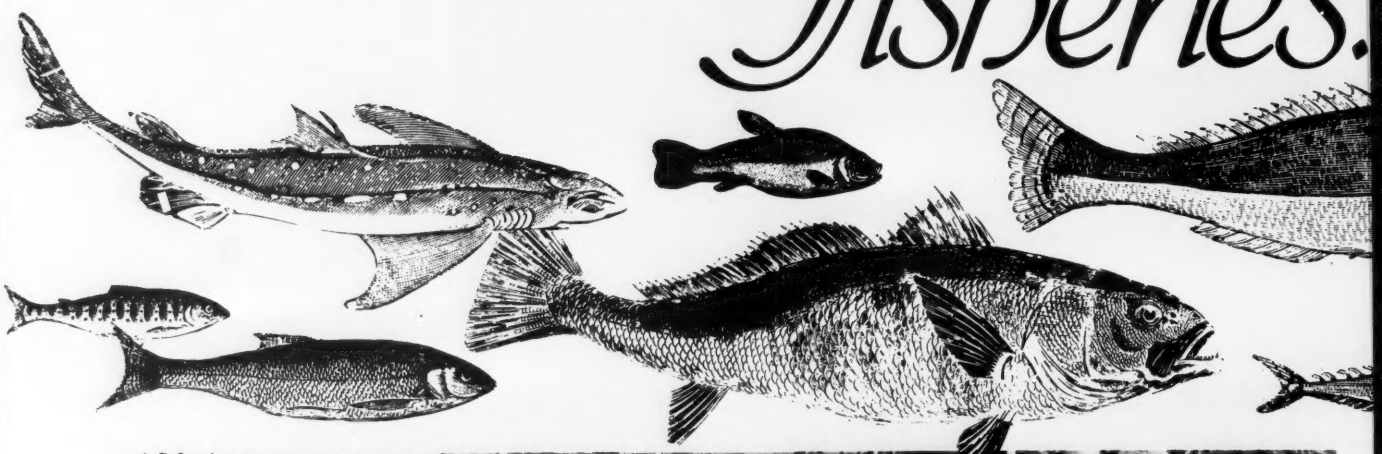
. . . The new regulations do not promise sweet harmony.

Planners forsee the Project as facilitating drainage and reducing flooding in about 790,000 acres of rich central Arkansan bottomland.



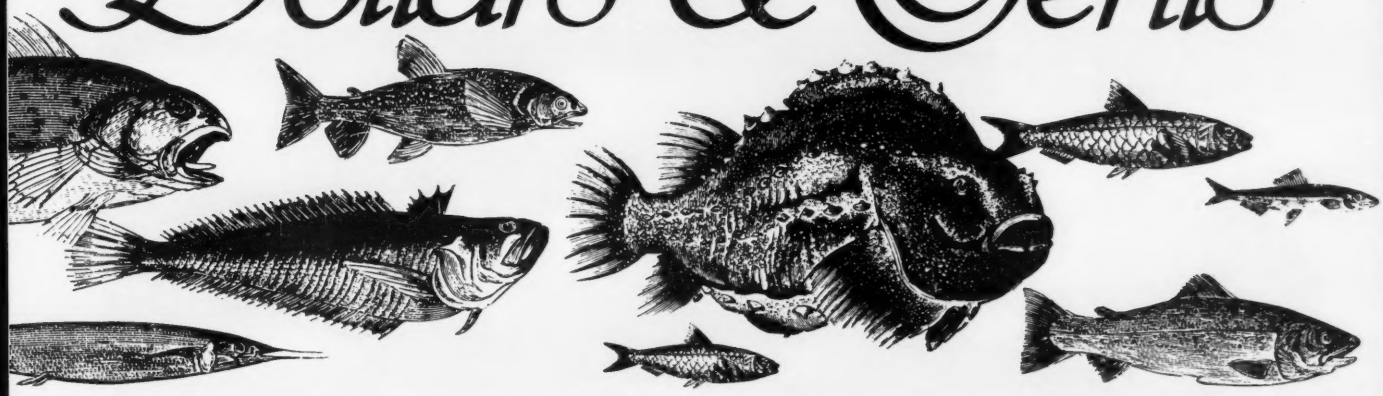
Fisheries.

by **Daniel R. Talhelm**



A fisheries management agency faces difficult choices about how to develop resources. Its decisions affect millions of people, some of them in ways that change their livelihoods and lifestyles. Here, using Michigan as an example, economist Dan Talhelm shows how economics can make fisheries management decisions more objective and describes the results of investigations into the economic value and impacts of Great Lakes fisheries.

Dollars & Cents



The fisheries in the Michigan waters of the Great Lakes have undergone a dramatic change. Commercial fishing has changed from a generations-old way of life for hundreds of families to a business venture involving only about 150 people today; from a boom industry to an aged, overcapitalized one. Until well into this century, interest in Great Lakes food production was much greater than interest in sport fishing. Now, however, the sport fishery is experiencing an unprecedented boom. There are some ten million angler days per year spent in pursuit of Michigan's Great Lakes fish. In contrast, there are only 17 million angler days spent on salt water in all five Pacific states. In Michigan, anglers harvest two or three pounds of Great Lakes fish for every pound harvested commercially. Total harvest is 50-60 million pounds annually. The Great Lakes apparently provide one of the more valuable sport fisheries of the world.

As one might expect, there is a lot of conflict between sport and commercial fishermen over who can make better use of the resource. This is not only true in Michigan, but all over North America, wherever the two groups compete for the use of the same resource.

Presently, in Michigan some Native American groups are also competing for the fishery. However, this is a legal fight with the Native Americans claiming unlimited fishing rights in about half of Michigan's Great Lakes waters. Since their interest is in commercial fishing and their direct control over sports fishing would be doubtful, commercial fishing could again dominate in those waters.

The Michigan Department of Natural Resources (DNR) has deliberately induced many of the recent changes. Commercial fishing has declined, while sport fishermen enjoy top quality fishing, largely because the DNR feels this is the wisest allocation of the resource now and is managing accordingly. This is a value judgment: the management agency feels that the value of sport fishing greatly outweighs the value of commercial fishing.

The problem is that these relative values have not, until now, been documented, leaving much disagreement about the accuracy of decisions based on them. Economics can aid the decision-making process by quantifying fisheries values. For example, preliminary studies indicate that the *net annual "social" value* of Michigan's Great Lakes sport fishery is about $250 million, and that of the commercial fishery about $2 million. Their *annual impacts on Michigan's economy,* on the other hand, are $200-300 million for the sport fishery and about $20 million for the commercial fishery.

Direct Resource Values

Fisheries have several kinds of values to society (see Table 1). The purpose of fisheries management is to permit society to obtain the greatest aggregate of these values, over and above their cost, from the resource in an equitable manner, over the long run. The most important of these values are the direct values received by the active users of the fisheries, primarily the sport fishermen and the consumers of fish caught commercially. Economists measure these values in terms of the willingness of users to pay for the use of the resource. This potential payment can be divided into (1) potential returns to the state to pay for the cost of providing for resource use and (2) the remainder. They consider the remainder to be potential "economic rent," defined as the net value of the resource to the public.

The concept of economic rent was originally developed to describe the value of land. Rent, or profit, was the value of products produced on the land, minus the cost of producing them. The concept is the same for fisheries resource values, except that the lakes are "common property"—owned by the state—rather than private

Dr. Talhelm is Assistant Professor of Fisheries and Wildlife Economics, Department of Fisheries and Wildlife, Michigan State University. This article is the result of research work in the Michigan Sea Grant Program sponsored by NOAA, Office of Sea Grant, U.S. Department of Commerce, under Grant #04-7-158-44078.

A sport fishing area on the breakwater at Port Washington, Wisconsin. (Photo by Suzanne Tainter)

property. The economic rent attributable to Great Lakes fish depends upon their productivity, the costs of harvesting, processing and distributing the fish, the willingness of anglers to pay for angling and of the consumers to pay for fish in the market, and the cost of management. There is no market for angling rights (except state licenses), so there is no market price for angling. Therefore the concept of economic rent must be broadened somewhat to include all payments anglers would be *willing* to make for the use of the resource. Economists also use the terms "net social value" or "social surplus" to refer to the same values. Thus "potential economic rent" as used here refers to values that differ considerably from the usual market values that we observe in everyday life ("marginal values"). It refers to aggregate values determined as if the choice were all or none, i.e., the value of having the entire fishery as opposed to not having it at all. The usual market values apply to various amounts of a good, not a choice of all or none.

Table 1

Social Values Derived From Fisheries Resources

I. Direct Values to Users—POTENTIAL PAYMENT FOR RESOURCE USE (potential economic rent plus recoverable cost of providing for resource uses)
   - A. Sport fishermen
   - B. Fish purchasers (consumers)
   - C. Other direct users

II. Indirect Values—ECONOMIC IMPACT (economic impact of user expenditures)
   - A. Geographic distribution of employment and income
   - B. Types of employment
   - C. "Temporary" employment and unemployment results from shift in expenditures

III. Other Values
   - A. Equity in resource allocation
   - B. Equity in income distribution
   - C. Value of "a way of life"
   - D. Location of employment and population
   - E. Ecological impacts
   - F. Value of keeping future options open (option value)
   - G. Existence values
   - H. Restraints on activities conflicting with fisheries (e.g. pollution)
   - I. Others

It is not necessary for a public agency to actually collect potential economic rent from anglers and consumers. Anglers and consumers may pay their share of management costs through license fees or taxes, but this payment is not economic rent; it is part of operating costs. Additional payment in excess of that which covers costs would be actual economic rent. We calculate the actual and potential revenue that could be collected, including rent, because that is the value or benefit of the fishery resource and reveals the importance the sportsmen and consumers place upon the fishery. The agency can then determine the net value—the potential economic rent—by subtracting management costs from its potential and actual revenue.

The agency is doing the best it can (in terms of efficiency) for anglers and consumers when total potential economic rent is maximized. For this to be true, any management project must be valuable enough that the anglers or consumers would at least be willing to pay for the management activities themselves, if necessary, over and above their other costs. In other words, benefits must equal or exceed costs. (The entire public interest in the fishery goes beyond angling and fish consumption, but for now our discussion will omit other values).

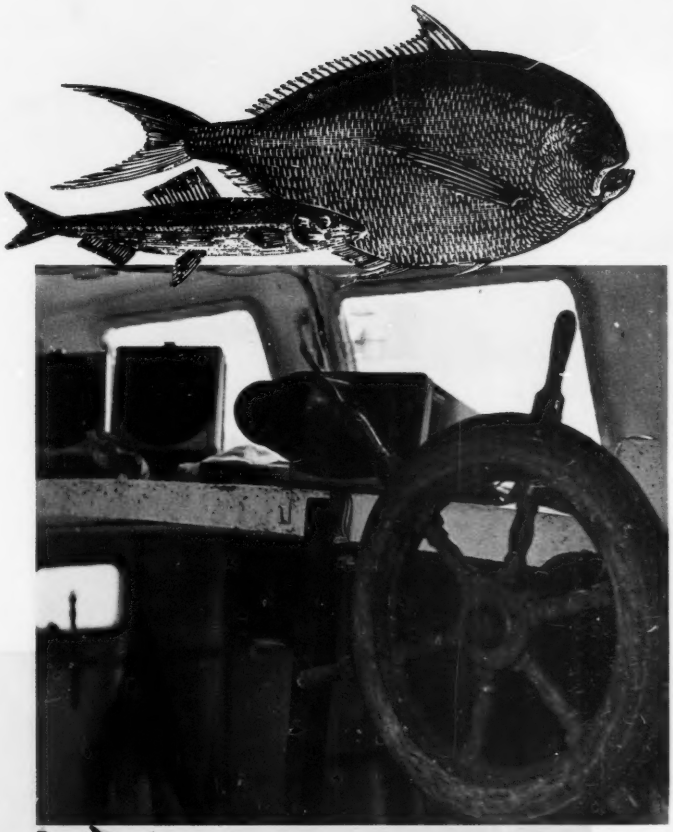
The problem, then, is to determine how much anglers

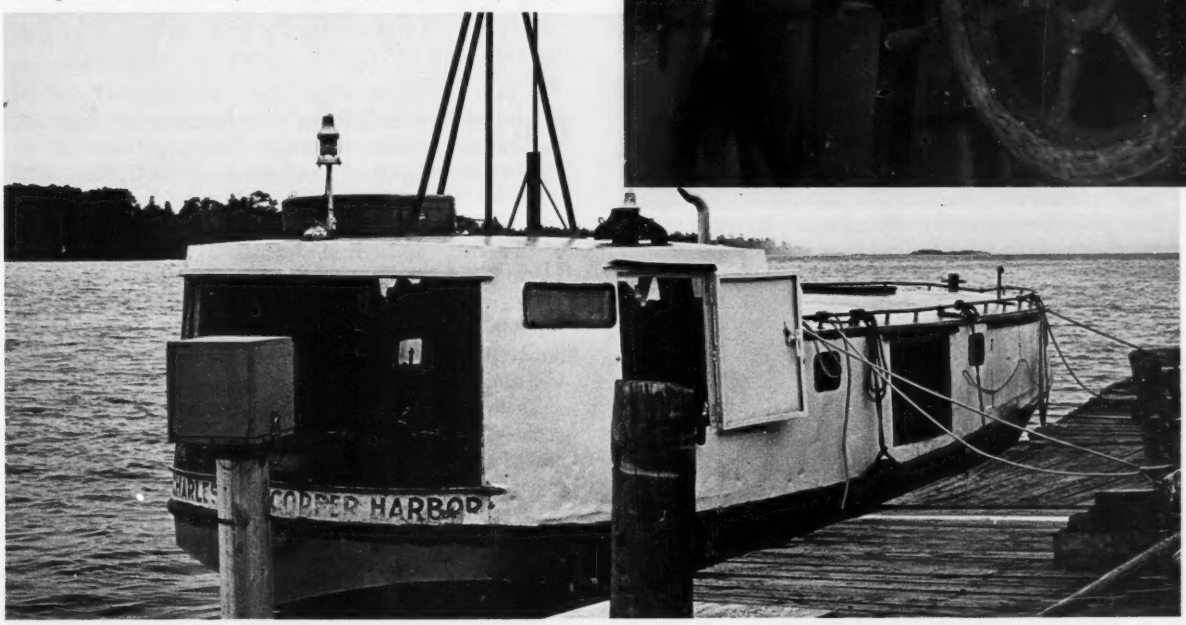
would be willing to pay for the privilege of fishing, over their present costs, and how much commercial fishermen would be willing to pay for their privilege, assuming that much of the fees would be passed along to consumers. This sounds simple enough, but in practice it is incredibly complicated. The problem has many dimensions: Each location differs in productivity and in proximity to population, each season of the year is different, each species has a different value to anglers and to consumers, the harvest of one species can affect other species, recreation quality depends upon many factors, the costs of commercial fishing methods differ, and there are a multitude of different management alternatives to be considered. Finding the value of a day's angling in the Great Lakes is much like finding the value of an acre of land: each one is a little different, and an average value is only misleading.

These values would be easier to find if there were a market for fishing rights. In Europe, there is such a market. For example, from 1973 to 1976, anglers in Scotland paid an average of $175 *per fish* to rent river "beats" for salmon fishing. After subtracting management costs, this is economic rent for the owner of the fishing rights, in the usual (market) sense of the term "economic rent."

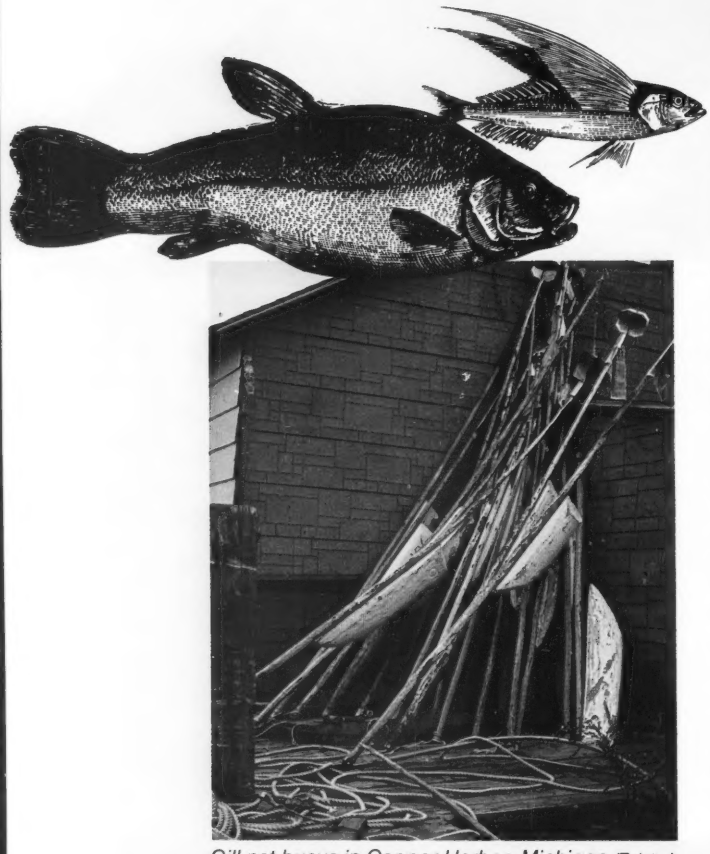
Sport fishing values *can* be determined, in the absence of a market for fishing rights, through some rather complex techniques that have been recently developed. First, angling quality must be identified. For example, one of the first studies of this kind identified several different kinds of salmon/steelhead angling in Michigan based mainly upon anglers' catch rates.

Second, the demand may be estimated for each of the different kinds of salmon/steelhead angling, for example. Each demand equation estimates the willingness of anglers





A commercial gill netter homeported in Copper Harbor, Michigan. Inset is the ship's wheelhouse and radar. (Tainter)



Gill net buoys in Copper Harbor, Michigan. (Tainter)

Great Lakes whitefish caught for the commercial market.
(Photo by Leslie Lin)

to pay for a particular kind of angling, and their willingness to accept other, similar kinds of angling as substitutes.

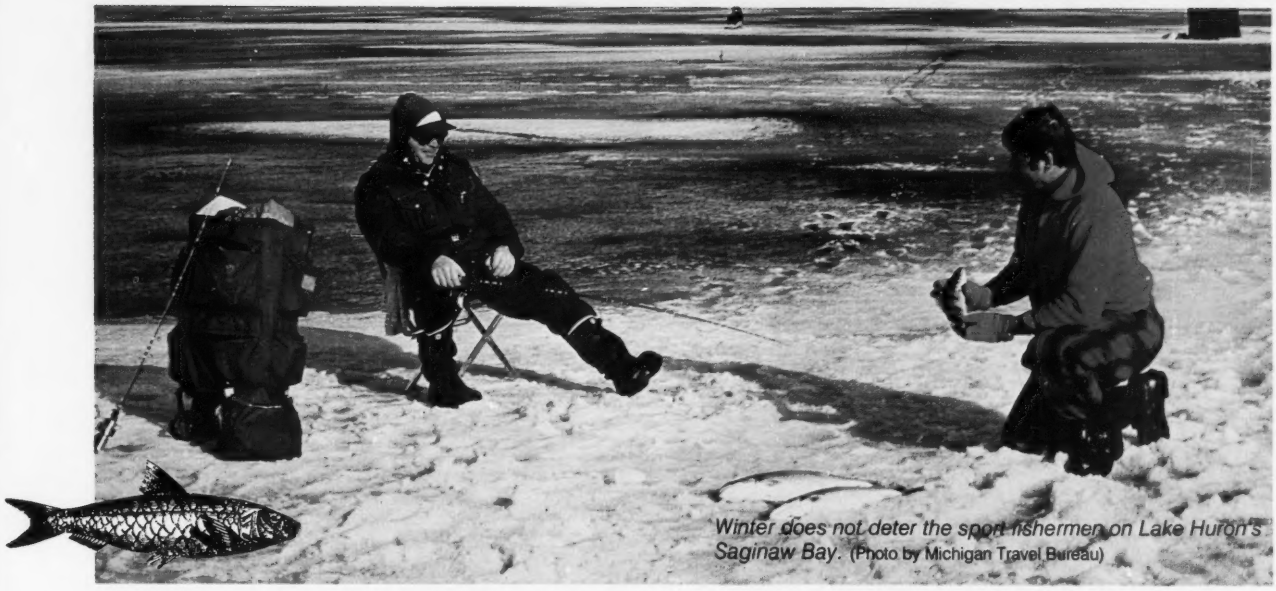
The final step is to construct a simulation model from (1) the demand equations, (2) an inventory of where each kind of angling is found and (3) information about where the anglers live around the state. Then we can estimate, for example, the changes in angling effort and in net value (or willingness to pay) for an increase in the catch rate of chinook salmon in a particular county. The calculation is complex, but the decision is simple; if the willingness of anglers to pay for the change is greater than the cost of producing the increased salmon run, then the project is a good one (providing that money is available and that even better projects do not exist).

In a study of the salmon/steelhead fishery in Michigan, we found that the net all-or-none value (potential economic rent) of the fishery for licensed anglers was about $30 million in 1970. In today's dollars, that would be about $45 million. Adding unlicensed anglers to that figure gives a value of around $75 million, plus or minus about $15 million. Expanding this figure to include all current fishing for Michigan's Great Lakes fish, we have a rough calculation of around $250 million per year. This estimate of net all-or-none value, or economic rent, does not include payment for fishing licenses and excise taxes on fishing tackle because those funds now pay most management costs. This may not represent the value of the fishery under optimal management, because further improvements are probably possible.

Comparable values for the commercial fishing industry may also be obtained through demand and supply analysis. We have just completed the first demand and supply analysis of the U.S. whitefish fishery. Whitefish demand is quite "elastic," implying that other foods, including lake trout, are readily accepted as substitutes for whitefish in the market. Michigan's "share" of the net all-or-none value, or potential economic rent, of the U.S. whitefish fishery in 1976 was estimated to be $1 million. Whitefish sales are about half of total commercial fish sales (in value) in Michigan.

Our commercial fisheries study has estimated costs and returns of different kinds of fishing operations in 1973 and developed a "bioeconomic model" of the whitefish fishery. The bioeconomic model in this case starts with a biological model of the population dynamics of whitefish, then adds information about fishing costs and value. Results showed that fishing effort is excessive in some areas, and that gear limitations seem to be imposing some "unnecessary" costs on fishermen. Economic rent received by producers (fishermen) is only ten percent or less of gross revenue.

The optimum level of fishing effort is the point where economic rent from production is maximized: where the cost of additional fishing equals the aggregate additional revenue produced. This point is usually slightly less than the effort required for maximum sustained yield. Whitefish fishermen in one district (Northern Green Bay) could realize an actual economic rent as high as 50% (between ⅓ and ⅔) of total revenue, simply by reducing effort by 50%, to the most efficient amount. The reduction in effort



Winter does not deter the sport fishermen on Lake Huron's Saginaw Bay. (Photo by Michigan Travel Bureau)

would release those unnecessary costs for more productive use elsewhere in our economy.

Releasing such unnecessary costs for other productive uses in our economy is the main reason for limiting the amount of commercial fishing effort, other than maintaining optimum yields of various species. Approximately the same level of catch can be obtained over a wide range of fishing effort. If the capital and labor producing unnecessary fishing effort have alternative uses, it would be more efficient to gradually eliminate that effort.

Assuming that the potential economic rent at optimum effort is 50% of present total revenue, the rent value of the entire commercial fishery at levels of catch in the early 1970's, but present prices, would be $2 to $3 million. Under the most optimistic conditions, the all-or-none potential economic rent would be only around $15 to $20 million. This estimate is based upon near-record harvest levels for the various species, and the assumption that even salmon and trout are entirely available for commercial harvest and sale at modest prices.

This is much lower than the sport fishing value of $250 million. One reason it is so much lower is that other kinds of fish are ready substitutes for Great Lakes fish in the food market, whereas substitutes are much less available for sportsmen. Both figures are only very rough calculations, however, based upon selected portions of the entire fishery.

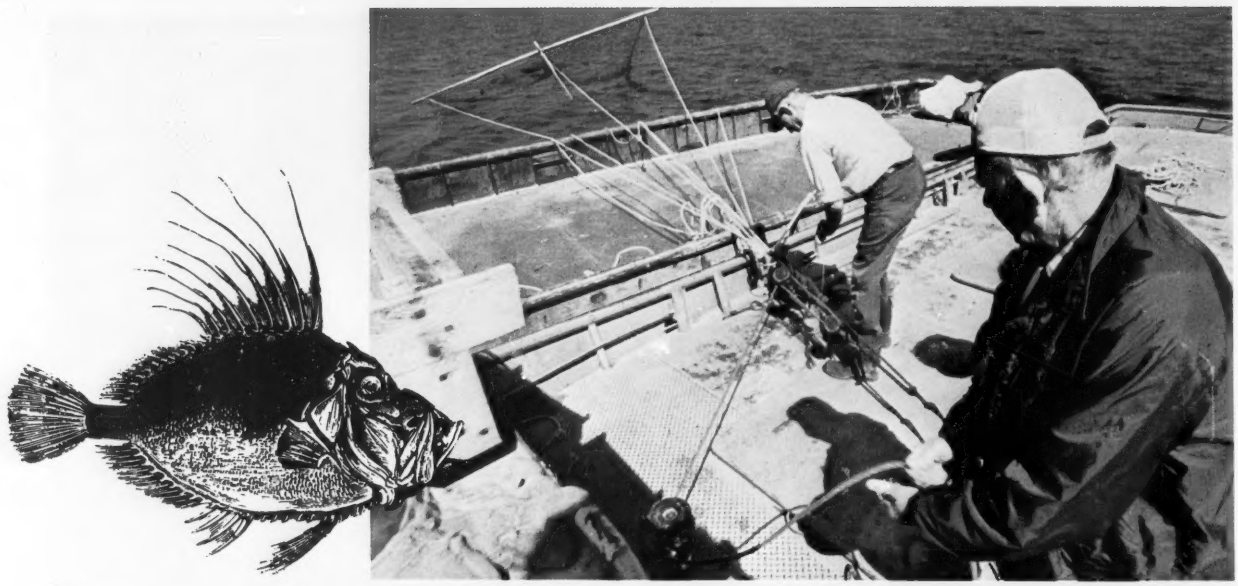
The present potential economic rent for sport and commercial fishing is about $253 million (Figure 1), assuming optimum commercial yield, given the present allocation between commercial and sport fishing. It appears that little could be done to increase the total value of the fishery by reallocating between commercial and sport fishing. This research makes it obvious that whereas in many cases sport fishing values are higher than commercial fishing values, in some cases, the reverse is true. However, we are just now developing the means to tell where, when and to what degree. Soon we may be able to precisely document many of the trade-offs.

Indirect Resource Values: Economic Impact

Another kind of economic value is derived from the impact of fisheries-related expenditures on various parts of the state. "Economic impacts" are the impacts of activities upon the geographical distribution of employment and of income flows in our economy. This should not be confused with resource values. Economic activity may owe its existence to a natural resource such as the fisheries, but the economic activity does not measure the value of the resource itself. For example, licensed and unlicensed salmon and steelhead anglers spent about $20 million for Michigan fishing in 1970. That was their cost of going fishing, so that is not economic rent. Potential economic rent was another $40 to $50 million. To illustrate this point with an extreme analogy, a tornado can bring about a large amount of expenditures in an area, but this is not viewed as a benefit.

The $20 million spent in Michigan probably was taken in minor amounts from many other potential alternative expenditures at many locations throughout the state and then actually spent in a concentrated area along Lake Michigan. This affects where people find work, the prosperity of various communities, and the services needed there. A shift in the locations of fish can shift employment and cause temporary unemployment. Information of this kind is very important for local and regional planning, but will probably have only a temporary, minor influence on the benefits of fisheries management. In the short run, the decision-maker should count as a benefit the income that is earned by those who would otherwise be unemployed, and as a cost the income that is lost by those who are put out of work elsewhere.

Expenditures have a "multiplier" effect as they are re-spent within the state. In other words, a portion of each dollar spent on fishing tackle is re-spent within the



Commercial fishermen set a Great Lakes trap net. The catch is removed about every 2-3 days. (Photo by Bruce Pollard)

Table 2

Summary of Annual Values of Michigan's Great Lakes Fisheries

	Sport Fishery	Commercial Fishery
I. Potential Economic Rent*		
A. Present	$250,000,000	$ 2,000,000
B. Under most favorable conditions (hypothetical)	?	$20,000,000
II. Economic Impact		
A. Expenditures	$100,000,000	$ 3,500,000 (ex-vessel value only)
B. Total impact in Michigan	$200,000,000 to $300,000,000	$20,000,000 or less

*Potential economic rent as defined here is the maximum potential willingness of anglers or consumers and producers to pay a hypothetical resource owner to use the resource, rather than to do entirely without that use. In addition, potential economic rent does not include the "owner's" cost of management, administration and enforcement. Willingness to pay in this case does not include any present user expenditures except profits earned by commercial fishermen (greater than "normal" returns on labor and investment). Such profits are very small at present. Sport and commercial license fees and excise taxes were not considered to be part of potential econonic rent as defined here because they are used to pay much of the cost of fisheries management. They can be considered part of the value and the cost of having fishing resources, however.

community, multiplying by some amount the effect of the expenditure on the community income. The total income in Michigan related to Great Lakes sport fishing is probably between $200 and $300 million per year.

In contrast, the $4.3 million dockside value of Michigan commercial fish in 1973 may have had a total impact of $16 million, including "value-added". ("Value-added" refers to the fact that processing, shipping, wholesaling and retailing add to the market value of fish). This is a combined "multiplier" and "value-added" factor of almost four. Currently the total impact is probably closer to $20 million.

Another economic impact is the increase in resort and vacation property values near good fishing areas. Increases in property values in such locations, over their values without the fishery, are attributable to anglers improving their access to the resource. Property ownership can be viewed as a technology employed by anglers to provide themselves with angling either at lower time and/or money cost or in a preferred fashion, compatible with their other activities. These advantages to anglers may also produce a slight increase in their willingness to pay (potential economic rent) for the use of the fishery. Impacts on property values are another important kind of economic impact, but are not measures of direct benefits (rent) of the fishery.

Other Resource Values

There are several other kinds of values attributable to the fisheries that may also be important in resource management (see Table 1). Most are difficult to quantify, and no specific estimates have been made, to our knowledge, but many or all of these enter into the decision-making process in various ways. Our representative form of government, including administrative agencies like the Natural Resources Commission in Michigan, is designed to hear and weigh all concerns of citizens, including unquantified

concerns such as these. Understanding these values better should make this weighing process more explicit.

One important concern is that resources be used in an equitable fashion. For example, what is a "fair" allocation of perch between anglers and non-angling consumers? Even more vexing is the question of the value of a change in equity. For example, if portions of certain perch stocks were allocated from sport to commercial harvest, aggregate potential economic rent and economic impact of the fishery would both probably be reduced. Anglers' losses would exceed consumers' gains. This would be a less efficient use of the fishery, reducing potential economic rent. But suppose it were also a more equitable solution (say, benefiting some who would otherwise be unable to eat perch). Does the value of the increased equity outweigh the loss in potential economic rent? Decision-makers are faced with a multitude of such questions. These questions might be answered to some extent by asking the public's opinions about their willingness to pay for specific changes in equity. However, this approach has two problems: people would have difficulty comprehending the question and giving a complete answer, and any answer depends to some extent upon the existing distribution of income. In any case, the fact that situation A is *fairer* than situation B does not necessarily imply that A is *better* overall than B.

Another important concern is equitable distribution of income in general, including the benefits of angling as a form of "real income." For example, keeping license fees low gives the poor a better chance to benefit from fishing. "Real income" equity is a concern of most of us, but resource management for this purpose is an inefficient way of improving the lot of the poor. For example, since license fees fund management programs, keeping license fees low also keeps the level of management and

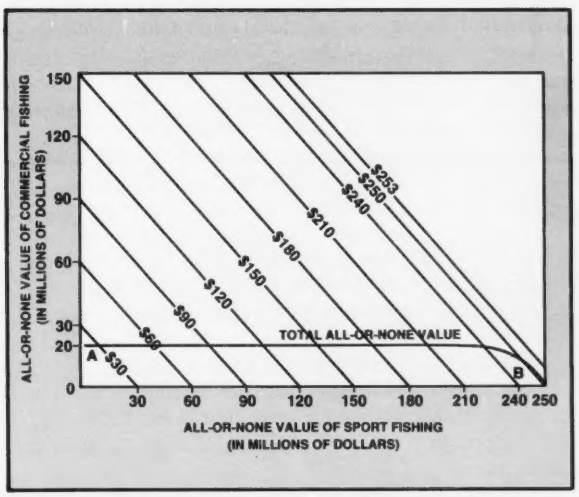


Figure 1. Hypothetical value possibilities curve for combinations of sport and commercial fishing on Michigan's Great Lakes and major tributaries. Based upon two estimated points, A and B, where A represents the maximum possible all-or-none value of commercial fishing ($20 million) and B represents the present all-or-none values of $3 million and $250 million for commercial and sport fishing, respectively.

A trophy lake trout.
(Photo by Great Lakes Fishery Commission)

enforcement low, to the disadvantage of most of the public. If our elected representatives dealt with income equity as an issue by itself, it would be of less importance in resource management. Perhaps we can assume that legislators have already considered and acted upon the income equity issue as much as the (voting) public wished, in which case resource management has a relatively small role to play in most cases.

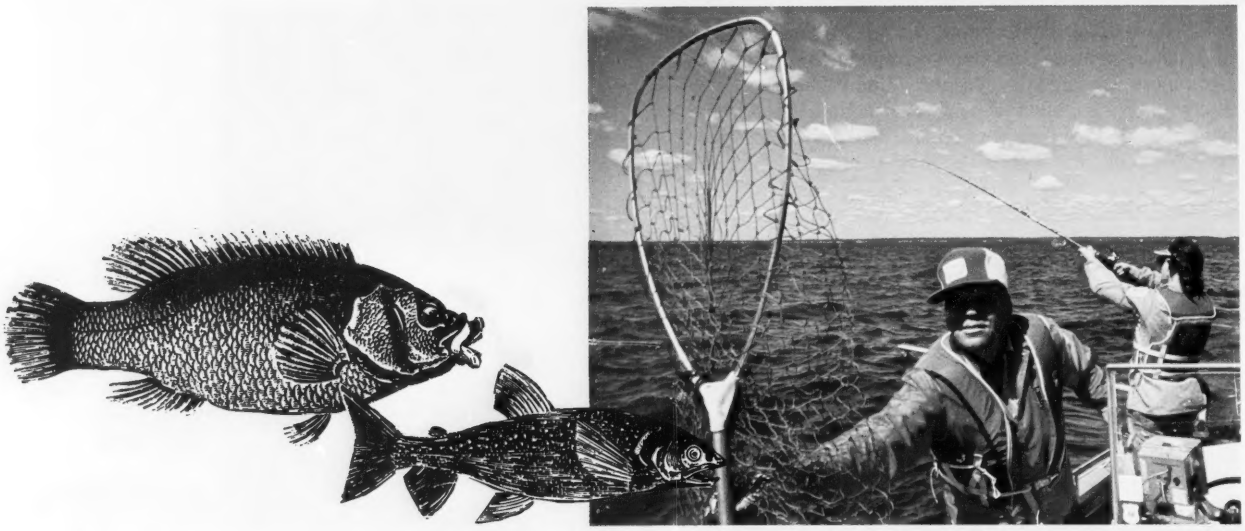
The dwindling of "old style" commercial fishing villages and fishing families in Michigan raises questions regarding the values of these institutions. Probably the major value to the public would come from preserving such historical attractions. Aside from this, the value of a particular "way of life" to a family could be measured in terms of the sacrifices the family is willing to make to avoid alternatives. The easiest of these sacrifices to measure is families' willingness to accept lower incomes. However, even this is difficult, because it is difficult to say what the alternatives might be in the long run.

The public may perceive some value in shifting employment opportunities—hence population—to certain locations in the state. The advent of the salmonid sport fishery has shifted some employment and probably some population from other areas of Michigan to coastal areas, particularly along Lake Michigan. This could have positive and/or negative values to the general public and to the people involved. Some of this value might be measured in terms of pay differentials.

An "ecological value" of the salmon and trout populations is their ability (apparently) to control the alewife population of Lake Michigan, thus preventing massive die-offs that foul the beaches. There are numerous other examples of beneficial and detrimental effects that fish have on our environment because of the nature of the ecological systems of the Great Lakes.

There is unmeasured but real value in keeping future options available in the Great Lakes. These values stem from the fact that human wants and needs and technology

The strike of a fish generates frantic action aboard a Lake Huron sport charter boat. (Photo by Michigan Travel Bureau)



change over time. The values of present opportunities must be weighed against the loss of future opportunities. For example, the extinction of a fish species or variety is irreversible (at present). Any possible future recreational, ecological, technological or other uses are foregone.

A related value of the fisheries arises from the fact that there are people who do not presently use them for food or recreation, but who derive benefits from knowing that they can fish for or purchase fish if they wish. People are willing to contribute to resource management to maintain their present options. These option values are usually not estimated in studies of recreation or food demand.

Closely related to option values are "existence values": the value of knowing that certain life forms or even ecological systems exist. Evidence of such values may be seen in the public sentiment for whales, porpoises and other animals, and for "undisturbed" areas such as wilderness. People are willing to pay to promote certain ends because of such sentiments. These values may be unrelated to people's other uses of the resource.

The existence of a fishery may preclude certain other direct and indirect uses of the lake. Considerable expense is incurred to prevent pollution and contamination. At least part of these expenditures, including foregone benefits available from DDT, PCB and other chemicals, are incurred for the purpose of maintaining a more valuable fishery. The expenses and foregone benefits are costs of the fishery.

Finally, there may be other values associated with Great Lakes fisheries. Researchers are continuing to explore the various values in an effort to provide more information about their nature and magnitude. In many cases, however, the work has hardly begun.

Conclusion

Most of the value of fisheries management is revealed in the willingness of users to pay, over and above their other costs, for the management results. The first studies of these values have shown that in the case where the choice is all-or-none—to have the use of the resource as opposed to not having it—the current sport fishing value for Michigan's Great Lakes is around $250 million and the commercial fishing is $2 to $3 million. Even under optimistic conditions, commercial value would be only six to eight percent of present sport value.

The impact of fisheries-related expenditures can be very important to certain localities, but this usually has little significance for the value of management, since positive impacts in one place are usually balanced by negative impacts elsewhere. Statewide, incomes related to the Great Lakes sport fishery are over $200 million and for the commercial fishery are about $20 million.

Despite the fact that sport fishing values greatly outweigh commercial fishing values, the greatest aggregate values can still be realized only by having both. Some important commercial species, such as chubs and whitefish, are seldom sought by anglers. Since these species do not appear to be detrimental to the sport fish stocks, efficiently utilizing them can only add to the aggregate value of the fisheries. In some other cases, the tradeoffs are less obvious. Where angling effort is relatively light, some commercial fishing may enhance overall fisheries values.

The DNR feels that the Great Lakes are still underutilized for both sport and commercial fishing. The future outlook is good for a small, but viable and fairly efficient commercial fishery together with an outstanding sport fishery.

A detailed economic analysis of management alternatives can provide useful information about these values and trade-offs, adding much more precision to the manager's decision-making process. However, care should be taken not to overlook unquantified benefits and detriments of many kinds. In many cases so little is known about certain values that all that can be said with certainty is that they exist. ■

BOOM & BUST: INVESTIGATIONS

by **W.D. Davies, W.L. Shelton, and D.R. Bayne**

Drs. Davies, Shelton and Bayne are fishery biologists on the faculty of Auburn University, Auburn, Ala.

Newly impounded reservoirs in the United States, particularly in the Southeast, typically provide excellent fishing, especially for carnivorous species such as the largemouth bass and crappie. Within a few years, however, fishing success appears to decline. Several factors are thought to contribute to the high initial angler harvest: The new reservoir provides a vast amount of unoccupied space, which fosters rapid expansion of the fish populations; inundated trees, stumps and other structures provide safe havens and subsequent good survival of young fish; flooding of rich bottom land contributes to water fertility, which leads to increased abundance of fish food organisms and enhanced fish growth. Many species are favored by the conditions in the new reservoir and reproductive success is high. This is true both for the largemouth bass and those species upon which bass normally feed. Thus, a condition exists where a large portion of the prey specie populations are of a size that can be eaten readily by bass. The end

Lab work is integral to fishery management data collection. Here, stomach contents are examined to determine food chain patterns.

Amity Point Recreation Area on West Point Lake. (Photos by Auburn University unless otherwise noted)

result is that the initial year class (the impoundment's first spawn) of bass show excellent growth and survival patterns.

In later years, the size and age structure of the fish community stabilizes. A larger portion of the fish biomass is composed of adult fish. The fish populations, in effect, reach an equilibrium where only those individuals lost to fishing and other types of mortality are replaced. As a result, fewer small fish that can readily serve as food for bass are present. Bass growth and survival are decreased, which subsequently results in fewer bass being caught.

Recruitment (additions to the harvestable population) within any year is also influenced by environmental factors—especially climatological vagaries. For example, physical factors such as water level fluctuation, temperature changes and wave action have been implicated as affecting reproductive success. Flooded terrestrial vegetation during the first and second year after impoundment provides safe havens for young fish, especially bass. There they have an opportunity to grow to a size less likely to be preyed upon.

As the reservoir ages, however, inundated structures decompose and prolonged leaching of inorganic nutrients from bottom soils decreases water fertility. Young fish are thus more vulnerable to predation, with the result that fewer fish—especially young-of-the-year largemouth bass—survive to replace those lost by fishing.

Most fishery biologists will generally accept the above sequence of events as a logical explanation for the "boom and bust" sequence characteristic of fish populations in newly impounded waters. There are scientists, however, that believe the sequence is largely a function of changes in the size structure of the fish populations themselves, and depends little on environmental changes. The latter hypothesis, if true, would offer fishery managers an opportunity to extend the "boom" sequence in heavily fished waters by regulating fishing-caused mortality in the population. A largemouth bass population, unlike some other animal populations, can be "stockpiled" through "catch and release" programs that result in a greater percentage by weight of bass in the system. This means that fishing success, at least initially, can be improved in terms of what is caught (and in this case released), at some expense in terms of harvest.

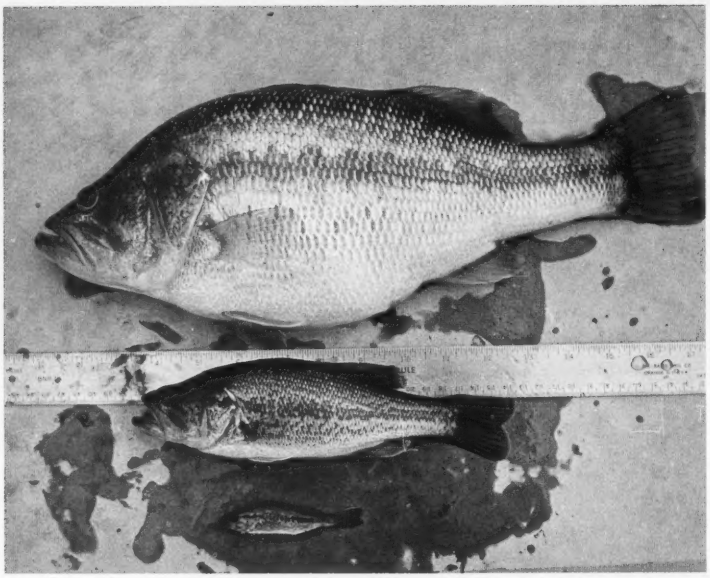
West Point Reservoir

West Point Reservoir (Alabama-Georgia) is a mainstream impoundment of the Chattahoochee River 5.2 km north of West Point, Georgia. Impounded in the fall of 1974 by the U.S. Army Corps of Engineers, the lake provides flood control, hydroelectric power, and recreational facilities. The lake has a surface area of 10,481 hectares, and, at optimum storage capacity a shoreline of 845 km. Flood control practices result in annual water level fluctuations of approximately three meters.

The reservoir was designed by the Corps as a recreational showplace for visitors. Upon completion, 113 km of paved roads will serve a total of 46 concrete boat launching ramps, about 1,500 picnic sites and 600 camping sites. Located in a heavily populated area between Atlanta and Columbus, Georgia and Montgomery, Alabama, the lake is expected to attract five million visitors annually.

The formation of West Point Reservoir offered an excellent opportunity to document the changes that take place within a new impoundment. Beginning in July 1975, the Department of Fisheries and Allied Aquacultures of Auburn University began gathering the information needed to formulate management policies for optimizing fishing and other recreational benefits for the reservoir.

A large number of largemouth bass were hatched during April-June of 1975. Those fish that spawned early (April) grew rapidly and were able to utilize the large numbers of threadfin and gizzard shad that had been spawned from mid-March through April; however, those bass hatched late (June) were smaller than the majority of prey species remaining in the population—and unable to feed on them. Thus, the 1975 year class of bass showed a wide variation in size by the following spring. Fish larger than 18 cm were in relatively good condition, while smaller ones appeared thin and often emaciated.



These bass were spawned in the spring of the same year; their size difference is a result of the late hatchers' inability to prey on the fast-growing shad.

Fishing in West Point Reservoir was relatively light during 1975. At this time the majority of bass in the population measured less than the 12 inch (30 cm) Georgia legal limit. By the spring of 1976, most of the faster growing bass had reached the legal size, and were attracting large numbers of bank and boat fishermen.

Creel Sampling

A statistically designed creel survey supplied data on monthly harvest, fishing effort and catch per unit of effort. Because of the large number of access points along the reservoir, the number of interviews with anglers which could be obtained at any one access point during a sampling period usually would be too few for our purposes. Thus, a roving creel survey, where fishermen are actively contacted, was a necessity.

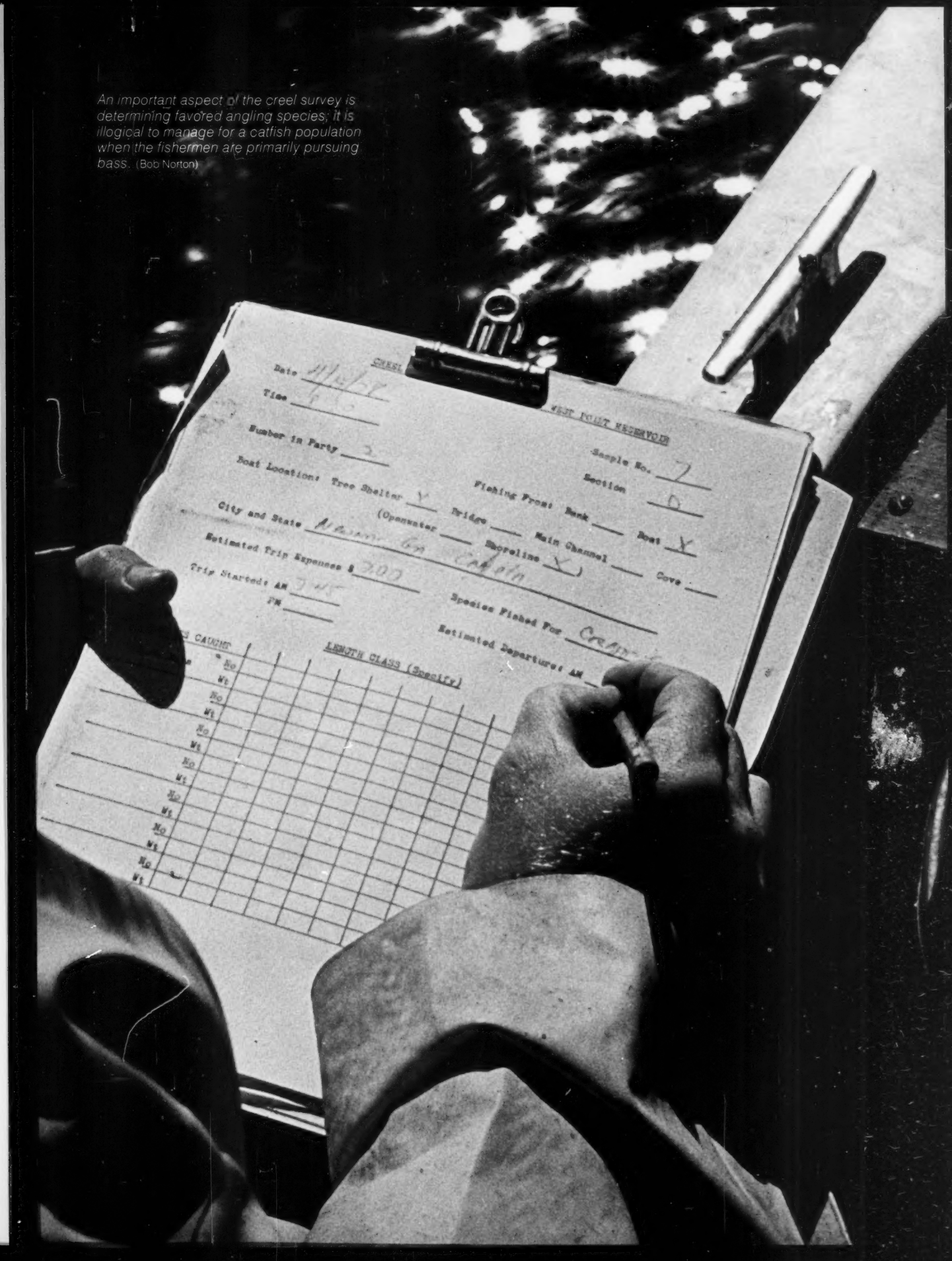
There were five basic features of this approach:

- The entire period for which the fishery was to be surveyed was divided into *time blocks*. (The amount of fishing expected to take place within these blocks should be similar.)
- Each time block was divided into *sampling units* (the time periods during which sampling will take place on the lake) so that all of the fishing time within a block is contained within the sampling units and the units do not overlap.
- *Sampling probabilities* proportional to the amount of fishing expected were assigned to the sampling units. The sum of the probabilities assigned to the sampling units within any given block equalled 1.0.
- Sampling units were randomly chosen within each block on the basis of the assigned sampling probabilities. Thus, the probability that sampling will actually be done during any given sampling unit is proportional to the amount of fishing occurring during that unit.
- Sampling on the water body is comprised of two components, *counts* and *interviews*. Counts of fishermen must be as instantaneous as possible, preferably being made from some vantage point for the entire body of water. Where this is not possible, systematic coverage of the lake is acceptable. It may be necessary to divide large lakes into sections, one section being sampled within any one sampling unit. The sections, like the sampling units, are randomly chosen with probability proportional to the amount of fishing expected to occur in the sections. After an angler count has been made, the time remaining in the sampling unit is spent interviewing fishermen. (Interviews should be representative of the water body being sampled, i.e. an entire circuit of the lake (or section) should be made during the interviews and an objective method of choosing the groups of fishermen to be interviewed (every group, every third group, etc.) should be employed.) The information recorded during an interview must include time spent fishing and weight of fish caught in order to estimate total harvest.

The West Point survey was divided into time blocks of one month and the blocks divided into sampling units of four hours. Any given day contained three sampling units spanning a 12-hour fishing period. These units were designated the AM, Noon, and PM sampling periods, and ranged from 0600 to 1000, 1000 to 1400, and 1400 to 1800, respectively. (Times were adjusted for Daylight Saving Time.)

Fishing patterns of Alabama's public fishing lakes show a marked difference between fishing pressure on weekdays and weekends; these two time categories were thus classified as separate sampling strata. The manpower available for the West Point creel survey allowed five sampling units to be worked monthly within each stratum; this was reduced to three units in the weekend stratum and two units in the weekday stratum during the winter (October-March) when the fishing pressure was expected to decrease.

A particular sampling unit was chosen by first randomly choosing a day, where all days within a month were given equal probability of being chosen, and then, within the chosen day, randomly choosing one of the three possible sampling periods with probability proportional to the amount of fishing expected to occur during that period. Expected fishing was estimated by fishermen counts made on the lake during the AM, Noon, and PM sampling periods. Sampling



An important aspect of the creel survey is determining favored angling species; it is illogical to manage for a catfish population when the fishermen are primarily pursuing bass. (Bob Norton)

Gill netting is another major collection effort undertaken during the Auburn study.

periods were chosen independently for each stratum each month.

The large size of West Point Reservoir required its division into six sections, one section being sampled during a sampling period. Since there are no vantage points, counts were made by making a circuit, by boat, of the section being sampled. The lake was divided into sections of a size that a complete circuit of any section took approximately one hour. Again, the section sampled was chosen with probability proportional to the amount of fishing expected. Expected fishing within sections was estimated from counts made by flying over the reservoir twice each month, once on a weekday and once on a weekend, while a creel survey was in progress. Sampling probabilities insured that data from all sections was included.

Sampling on the lake was conducted by choosing at random (by coin toss) whether counts or interviews would be made first, and also at random (again by coin toss) the direction (right or left) in which the creel clerk circled the lake section. Groups of fishermen interviewed were objectively chosen so that one complete circuit was made during the time alloted to interviews. During each interview, the number, lengths and species of all fish caught were recorded. The length of a fishing trip at the time of interview (incompleted trip length) was an estimate based on the fisherman's memory of what time he began fishing. Using this sampling scheme, where months are stratified into weekdays and weekends, the data were expanded as for any stratified random sample.

Tagging Program

Concurrently, a tagging study was undertaken to determine what portion of the population of legal size was being harvested. During 1976, 1,351 bass were electrofished, tagged and released back into the reservoir. No reward was offered for returned tags and only 78, or about five percent, were reported. Based on estimates of fishing pressure and the number of harvestable bass, this percentage appeared to be unrealistically low.

In 1977, the tagging program incorporated a reward system to stimulate reporting of tagged fish caught. Three tag colors were used. The ratio of different colored tags returned would not only provide information on the most efficient reward system, but would give a factor for correcting the estimate of harvest rate. White tags carried no monetary reward, blue tags were valued at $5.00 and red tags had a variable reward ranging from no monetary value to $500.00. For any tag returned, a letter was sent detailing the study and telling when and where the fish was released.

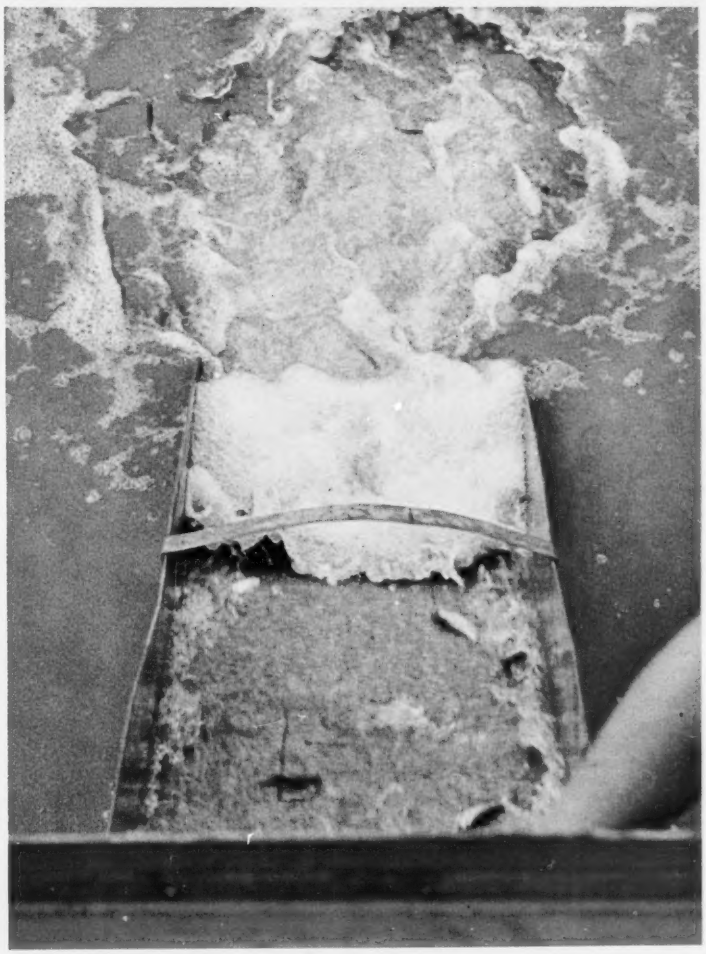
From March to June 1977, approximately 466 fish were marked with each color tag, for a total of 1,398. Posters illustrating the tag and informing the public of the reward system were placed around the reservoir. Frequent talks to fishing clubs, church groups and civic organizations also helped to publicize the tagging program.

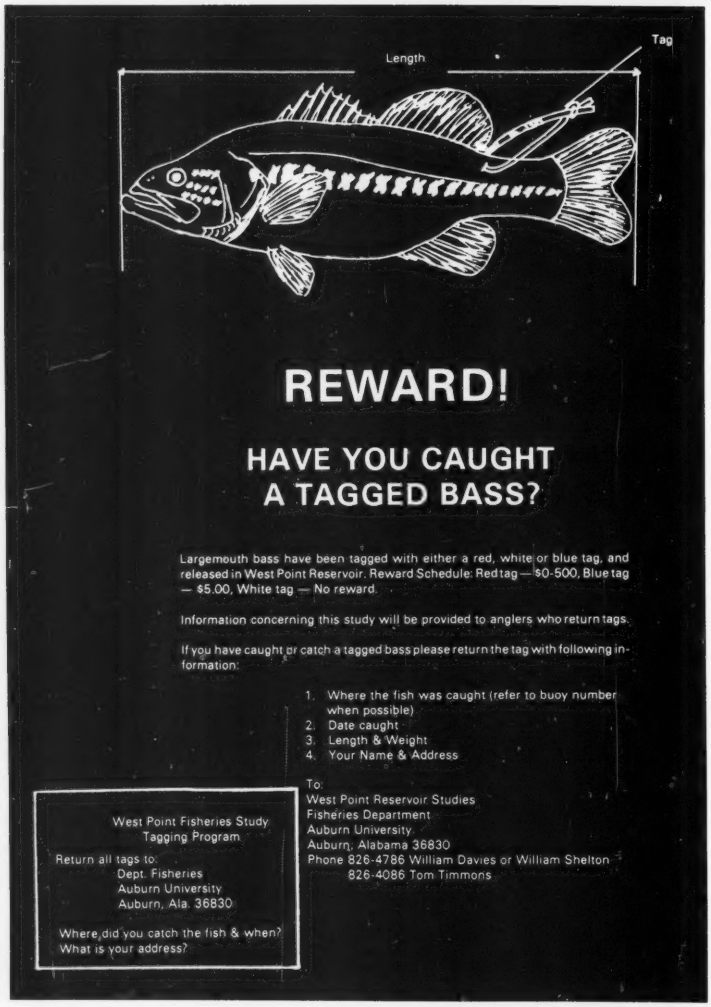
As of September 1977, returns of differently colored tags varied significantly:

Tag Color	White	Blue	Red
Number of fish tagged	466	468	464
Number of tags returned	47	84	129
Percent returned	10	18	28

The return ratios are approximately 1:2:3 for the white, blue, and red tags, respectively. Since there is no reason to believe that color alone would influence fishermen to return the tag, the obvious conclusion is that the variable value system, even with a probability of no reward, provided higher incentive than a fixed, but modest sum of money, and that both encouraged higher returns than a system that offered no reward.

Threadfin shad, an important foodfish for game species, were stocked in West Point shortly after impoundment.




Length
Tag
REWARD!
HAVE YOU CAUGHT
A TAGGED BASS?
Largemouth bass have been tagged with either a red, white or blue tag, and released in West Point Reservoir. Reward Schedule: Red tag — $0-500, Blue tag — $5.00, White tag — No reward.
Information concerning this study will be provided to anglers who return tags.
If you have caught or catch a tagged bass please return the tag with following information:
1. Where the fish was caught (refer to buoy number when possible)
2. Date caught
3. Length & Weight
4. Your Name & Address
To:
West Point Reservoir Studies
Fisheries Department
Auburn University
Auburn, Alabama 36830
Phone 826-4786 William Davies or William Shelton
826-4086 Tom Timmons
West Point Fisheries Study
Tagging Program
Return all tags to:
Dept. Fisheries
Auburn University
Auburn, Ala. 36830
Where did you catch the fish & when?
What is your address?

These data provided a more realistic estimate of the rate of harvest for bass in West Point Reservoir. Based on the rate of returns for red tags, the *minimum* estimated rate is approximately 28 percent. This means that at least 28 percent of the harvestable size bass were caught by fishermen. For a large body of water such as West Point Reservoir a 28 percent rate is considered high. Fishing, then, during 1977, has been an important factor contributing to the total annual mortality of the bass population.

This means that in 1977 (and very probably in 1976 also) a significant portion of the initial year class (1975) of largemouth bass was being harvested. As a result, after July 1977, very few largemouth bass from the 1975 year class were being caught by fishermen and the remaining fishery at this juncture was being supported by the smaller, slower growing 1976 year class.

Rotenone Sampling

These changes in the 1975 year class of largemouth bass were revealed in the results of blocking off 0.5 to 1.0-hectare coves with a net and applying a fish toxicant (rotenone) in 1975, 1976 and 1977. The entrances to the coves were blocked with a 0.5 cm mesh net so that no fish could enter or leave the area. Emulsified rotenone (5 percent) was pumped into the cove, while potassium permanganate was dispersed outside the cove to detoxify any rotenone drifting outside the netted off area. Distressed fish were collected for a 2-3 hour period and again 24 hours later to assure a total collection.

In effect, we were censusing the fish populations present in the cove at the time the net was placed in position. This permitted an evaluation of the change in size and age structure of the fish populations that normally inhabit the coves and margins of the reservoir. The average standing stock (pounds per acre) of largemouth bass recovered in 1975, 1976 and 1977 was 30.4, 14.0 and 7.5, respectively. This supported our conclusion that the initial year class of bass had suffered a high rate of mortality during the -3year period. Additional supportive evidence came from the estimated size structure of bass being caught during March-April of 1978, and, further, from a survey of fish caught during a September 1978 Bass Anglers Sportsman Society (B.A.S.S.) tournament that revealed only a small fraction of the fish caught could conceivably be of 1975 year class.

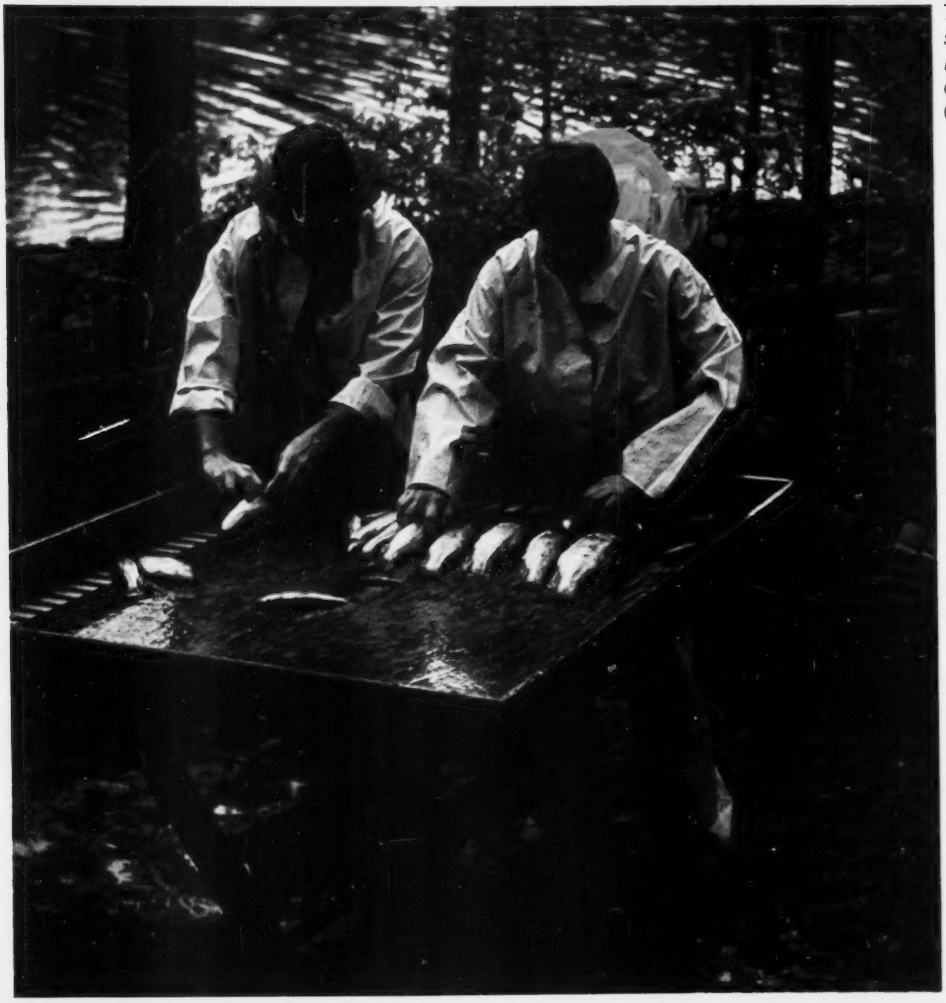
It is possible that a large number of 1975 year class bass still existed in the reservoir and our inshore sampling was biased toward only sampling smaller fish. However, very few larger fish (4-6 pound range) that could realistically be from the 1975 year class were represented in the creel.

The estimated rate of exploitation does not represent "overfishing" in the classical sense that the reproductive potential of the population

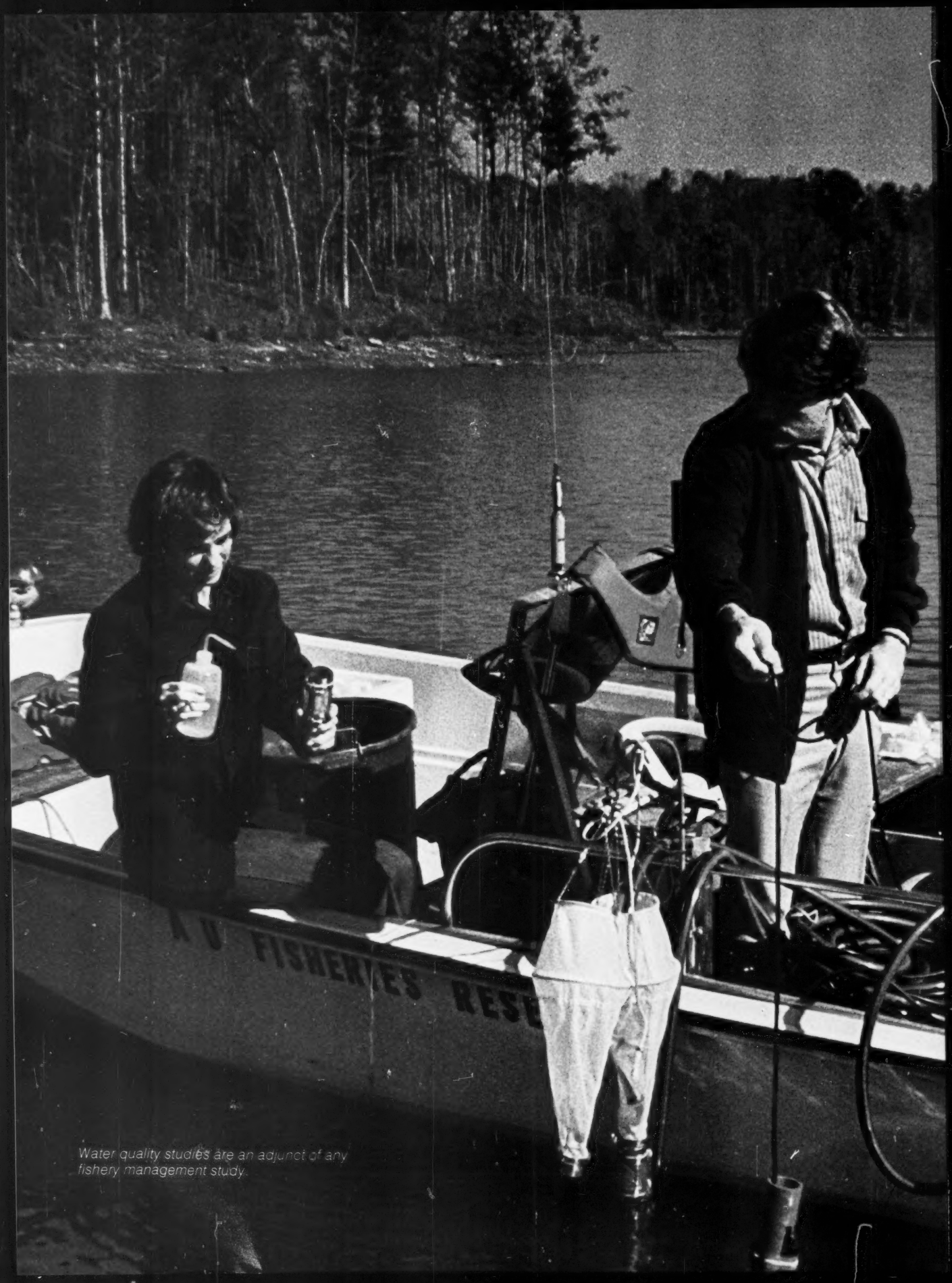
Following breakdown by specie, fish are sized and weighed by size-group. (Bob Norton)

has been hindered. Exploitation, has, however, restructured the size composition so that the majority of the fish harvested are small. The altered size structure not only affects the quality of fishing, but perhaps equally important, a change in the predator-prey relationship. In a practical sense, the small average size of bass in the reservoir is limiting bass production. A large portion of the available prey is too large to be effectively used as food by bass, while prey of the appropriate size is relatively scarce. As a result, growth and the production of bass is less than what it might be if the population was structured with larger fish.

Water quality studies designed to determine whether chemical and physical requirements of fish in West Point Reservoir are being met have been conducted at regular intervals since impoundment. Samples from seven stations and at various depths from the surface to the bottom



The fish species are segregated and measured at on-shore counting tables. (Bob Norton)



Water quality studies are an adjunct of any fishery management study.

were taken throughout the year at regular intervals to document seasonal changes in water quality. A total of 16 physical and chemical measurements was determined by standard methods.

The reservoir typically stratifies thermally and chemically during warm weather months (June-October) and deeper waters may repel fish during the period, due to low oxygen content and the buildup of noxious gases. This condition is normal in large mainstream impoundments of the southeastern United States and is not considered a hindrance to the establishment and maintenance of a sport fishery. West Point Reservoir is further subject to inflows of waters heavily laden with colloidal soil particles, particularly during the winter and spring months. The resulting turbid conditions drastically reduce light penetration during these periods. Water hardness and alkalinity are relatively low (< 20 mg/1 as $CaCO_3$), but the important plant nutrients nitrogen and phosphorus are abundant—particularly in the reservoir headwaters and Yellowjacket Creek, which receive treated wastewater from the cities of Atlanta and LaGrange, Georgia, respectively.

Accompanying limnological studies were also carried out to determine if plant nutrients were being utilized efficiently in the production of a food base for fish food organisms. Measurements of the primary productivity (rate of carbon fixation by the phytoplankton as determined by the carbon-14 method), standing crop and composition of plankton communities and qualitative and quantitative estimates of bottom dwelling invertebrates have revealed that West Point Reservoir is a fertile lake, in that it has produced sufficient fish foods to support a relatively high fish biomass (350 kilograms per hectare). There have been numerous attempts to relate various environmental factors to fish production, but no single factor explains a significant amount of variation therein. However, if more than one variable is considered, the correlation improves considerably.

To date, observed changes in the black bass population structure are apparently not due to any changes that have occurred in the physical and chemical quality of the environment, nor in the production of invertebrate fish food organisms. They are, apparently, a product of the growth and survival rate expressed by the initial year class of bass in a new reservoir.

In summary, while bass fishing remains good on West Point Reservoir, the boom appears to have passed prematurely. Perhaps in other new reservoirs regulations that limit the harvest of the initial year class would permit the population to develop greater depth as subsequent year classes are recruited. Fishing success for the trophy bass would therefore improve as bass of a larger size accumulate in the reservoir. ■

For accurate sampling, ALL fish species killed must be retrieved and counted.

PROJECT CLEARWATER

by **Gerald R. Calhoun**

The Roelkey farm in Frederick County, Maryland, "before" Project Clearwater. (Photos by Katherine C. Gugulis)

Skeptics shook their heads last fall when the Catoctin Soil Conservation District announced that it would totally renovate a badly eroded farm in Frederick County, Md., in a single day—all in the name of water quality.

By late afternoon, however, there were few skeptics left among the 12,000 spectators who came to view the transformation. Hundreds of volunteers with donated materials and equipment were performing on schedule, and Warren Roelkey's rundown farm was beginning to take on a new look of prosperity. By the end of what Acting Maryland Governor Blair Lee called a "truly inspiring day," Roelkey's 245 acres were a showcase of soil and water conservation.

Billed as Project Clearwater, the event was fashioned after field days held in the forties and fifties. A massive conservation workshop, it was held "to show that soil conservation is as valid for controlling water pollution as it is for increasing productivity," according to Daniel C. Poole, project chairman.

Mr. Calhoun is Maryland State Conservationist for the U.S. Department of Agriculture's Soil Conservation Service in College Park, Md., and is president-elect of the Soil Conservation Society of America.

Meeting the Challenge

The impetus for Project Clearwater was Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (amended in 1977 and renamed the Clean Water Act). The law calls for the control of nonpoint source pollutants—those contaminants contained in runoff—by 1983.

For farmers, that means controlling the sediments, chemicals, pesticides, and animal wastes that are washing off their land into streams.

States were given until the end of 1978 to come up with a plan to control nonpoint pollution. (Some later received 6-month extensions.) In Maryland, this planning is being carried out by three agencies—the Maryland Water Resources Administration, the Baltimore Regional Planning

WAKING UP TO WATER QUALITY

The Roelkey farm "after" Project Clearwater.

Council, and the Washington Council of Governments. The Maryland State Soil Conservation Committee and soil conservation districts are working with these "208" planning agencies, as are districts across the nation, to develop a strategy for combating agricultural nonpoint pollution.

The nation's agricultural community was not overjoyed with the prospect of having to deal with such a wide-ranging problem and one that is rather hard to alleviate. Visions of having to fence off their streams, construct expensive structures to process animal waste, and enclose their property with erosion fences caused alarm. Such proposals by some environmentalists seemed not only uneconomical to farmers, but also just plain impractical.

Conservation districts were quick to point out, however, that the technology for controlling sediment—the largest source of water pollution by weight and volume—had been around for decades. Conservation practices, installed according to a systematic plan, can dramatically reduce soil erosion. Control erosion, officials argued, and you'll automatically cut down on the sediment—and accompanying chemicals—leaching into streams.

When it became apparent that both farmers and regulation writers needed some convincing, Catoctin Soil Conservation District supervisors decided to hold the field day.

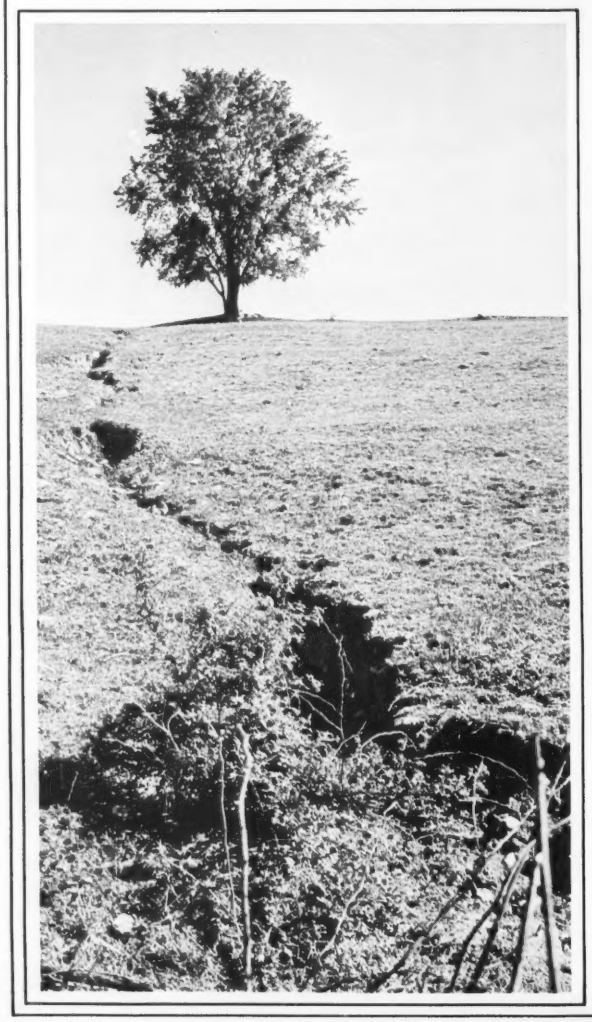
"We wanted to show the regulation writers that a voluntary approach to pollution control through traditional soil and water conservation practices would work. And we wanted to encourage those farmers who aren't practicing conservation to clean up their act before the government does it for us all," explained Poole.

The Plan

According to Paul Edwards, the SCS district conservationist who worked with Mr. Roelkey to design the conservation plan for Project Clearwater, the practices installed will help cut soil erosion on the farm by about 80 percent. That means about 40 tons of soil will now leave the farm each year

Roelkey's barnyard sloped down toward a stream and posed a serious pollution problem . . .

Poor vegetative growth in some areas, and up and downhill plowing in others, caused an extensive gullying problem.



and enter adjacent streams compared to about 350 tons annually in past years.

Cleaner water downstream is not the only benefit from the work that was done, however. The farm's productivity will also increase. Edwards predicts a 25 percent increase in corn production next year and a 50 percent increase in pasture grazing capacity.

In all, 13 different soil and water conservation practices were applied during Project Clearwater. Says Edwards, "Our strategy is to handle the raindrops from the time they strike the surface of this farm until they leave by the flowing stream."

Roelkey says he was delighted when his farm was chosen for the project even though he knew it would mean relinquishing much of his family's privacy. He agreed to it, however, because he had become distressed in recent years about the tremendous amount of soil washing off his steep fields and silting in nearby streams.

In anticipation of the field day, Roelkey's cornfield had been planted on the contour in early spring. About 80 acres of cropland were converted to contour stripcropping—a decades-old practice that alone can reduce erosion up to 75 percent. During Project Clearwater, every other strip was cut for silage and planted with a mixture of hay and timothy. These alternating strips of a close growing crop will trap sediment from the cultivated rows above. The silage—about 500 tons worth—was stored in a newly built, concrete-lined trench silo. The old trench silo was pushed in because liquids from it were draining directly into a nearby stream.

Bulldozers and graders constructed nearly a mile of diversion terraces—shallow, grass-lined channels that divert runoff around hillsides and greatly reduce the erosive force of the water. Gullies were pushed in and replaced with sod waterways to safely transport runoff from the diversions to the stream below.

To promote better plant cover, pastures were limed and seeded. An old abandoned orchard, where trees had become

. . . barnyard "rehabing" included installing a new fence and moving the hogs to a new barn away from the stream.

scraggly and the ground cover sparse, was cleared and seeded to orchardgrass and clover.

One of the most dramatic transformations occurred in a wet, low area near the barn. Here, bulldozers scooped out a new 1.1 acre pond, which, when filled, will trap sediment and supply water for the farm stock animals and recreation for the family.

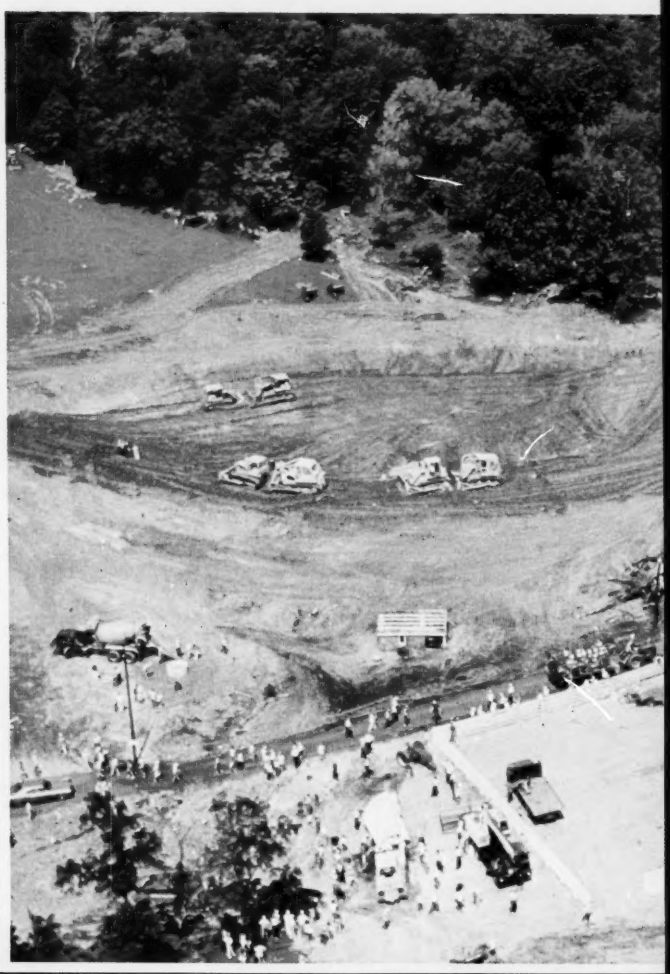
The pond will also supply two new watering troughs that will make water accessible to livestock and keep the animals out of streams. Railroad ties and crushed stone, forming a walk-in livestock drinking facility, were arranged along the banks of another stream for the same purpose.

To encourage growth of the strongest and most productive species, the woodland was selectively thinned. The resulting timber was cut and used for repairs and fence posts. About 1½ miles of new fence was laid out on the contour of the land to control livestock grazing and keep them from trampling the undergrowth in the woods. Drainage tile, installed with

A system of contour stripcropping and diversions will reduce erosion on Roelkey's cultivated fields by about 80 percent.

So much topsoil has washed away from this field the bedrock is exposed. The Roelkey fields were losing about 350 tons of soil annually prior to Project Clearwater, a figure that has now been reduced to about 40 tons.

Bulldozers scooped out a 1.1 acre pond that will provide recreation for the Roelkey family and water for the livestock troughs.



an innovative laser-operated trenching machine, will restore about 5 wet acres to production.

Workers also built a new hog barn, landscaped the lawn, and repaired and painted the old barn. A new well was drilled to supplement the house and barn water supply.

Old-time Cooperation

Community spirit is a longstanding tradition in Frederick County. Thirty years ago, a similar demonstration was held on the Thrasher farm across Middletown Valley from the site of Project Clearwater. Many remembered the Thrasher field day and readily pledged their support for Project Clearwater.

"The field day was a project based on faith," says Poole. The district embarked on its plans with a budget of only $2,000. Early in the planning phase, however, the County Board of Commissioners granted the district $17,000 in "seed money" to defray part of the administrative costs. It wasn't long before donations of cash, materials, and equipment from 200 clubs, businesses, and individuals began coming in.

Altogether, about $24,000 worth of donated materials and equipment went into the Roelkey plan. Edwards readily admits that some of that went for show. "We had to do some things differently than we normally would," he explained, "because we were trying to accommodate thousands of spectators and get the job done in one day. In fact, we had more offers of equipment than we could use."

He estimates the average farmer could probably accomplish the same thing for $15,000 if incorporated into his normal operation over an 8- to 10-year period.

About 180 pieces of farm machinery and heavy equipment swarmed over the farm as workers sweated in the sultry weather. Much of the actual work was done by Farm Bureau, Ruritan, Young Farmers, Grange, and Future Farmers of

America members as well as by garden and other civic club members. Others volunteered their time or were paid by their companies.

The Soil Conservation Service designed the conservation plan, the Extension Service provided the barn and landscape designs as well as advice on the livestock operation, and the Maryland Forest Service selectively thinned the woods.

The Maryland Water Resources Administration installed a water quality monitoring station. Results from a 3-month testing period before the project will be compared with test results during the same period next year.

Loss of a Resource

How great a problem is erosion? A recent study by the Soil Conservation Service puts the average rate of erosion on the nation's cropland at 9 tons per acre. That's two to three times faster than topsoil forms. If we continue to lose our soil at this rate, says Edwards, we may be facing a food production crisis greater than our energy crisis.

An aerial view of the Roelkey farm during Project Clearwater shows the magnitude and farm-wide application of the conservation measures. About 12,000, aboard hay wagons and on foot, viewed the field day.

Of the 3 to 4 billion tons of soil that erode from U.S. land each year, about 1.3 billion tons end up in streams, lakes, and reservoirs. That's enough to fill a train of freight cars stretching from the earth to the moon and halfway back.

Although some two million landowners cooperate with conservation districts by installing conservation measures, other farmers and landowners either don't notice erosion or ignore it. The deep gullies of the Dust Bowl days are seen less frequently today. Most soil is lost through sheet or rill erosion, an insidious process that often goes unobserved.

There are other reasons for today's erosion problem. During the mid-1970s when corn prices were high, many farmers went all out on production. Despite urgings by conservationists to protect as well as to produce more, they planted fencerow to fencerow, disturbing many acres that never should have been plowed. Later, when the push for production slackened, many of the fields were not given the remedial conservation treatment needed.

The rise in absentee ownership of farmland also accounts for why many farmers do not practice conservation. The farmer who tills rented land may have no vested interest in conserving soil—or his lease may be very short. Meanwhile, the owner may not want to pay for practices to conserve topsoil when he plans to sell the land for development anyway.

Large scale production has not helped either. Large equipment needs large fields to operate in efficiently. Thus, the fencerows and windbreaks are removed in an expediency that will prove costly in the long run. Farmers say that some practices, like contour stripcropping, are difficult with today's large machines. That's one excuse that doesn't hold with conservationists. Counters Edwards, "We had some of the biggest equipment in the county working on the Roelkey farm."

Granted, he says, soil and water conservation does require better management skills on the part of the farmer. But, it can be done.

And, of course, there are the costs of installing conservation practices. Cost sharing funds under the Agricultural Conservation Program are available for some practices and may be available later under the Rural Clean Water Program

A walk-in livestock water facility, built from railroad ties and crushed stone, will keep livestock from damaging the streambank.

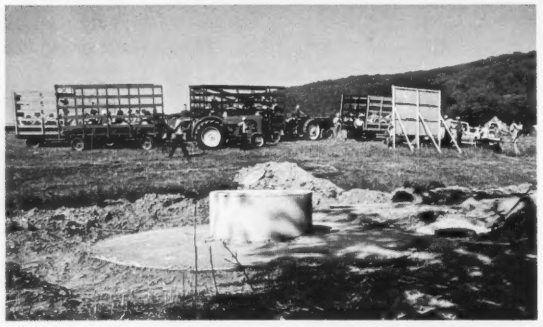
also authorized by the Clean Water Act of 1977. A few states also provide cost-share funds. Yet conserving soil is still largely an investment that the farmer must absorb.

Education Needed

We will not know until states finalize their "208" plans whether the tried and true conservation practices applied on the Roelkey farm are sufficient to meet the nation's clean water goals. But they are a step in the right direction.

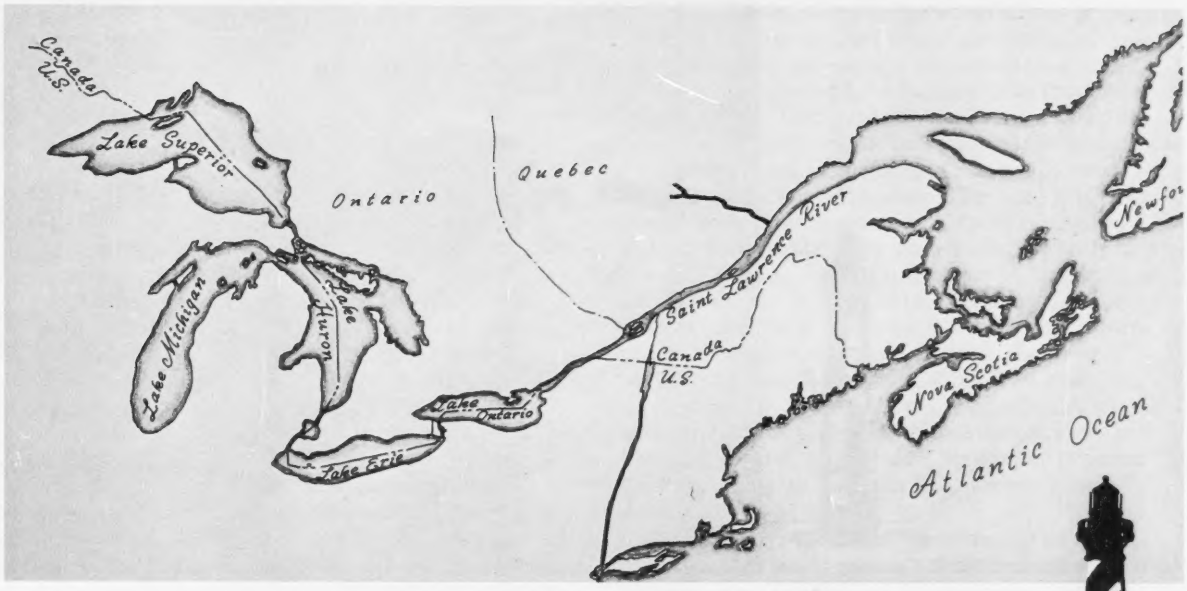
It is apparent, though, that both institutional changes and economic incentives are needed before soil and water conservation will become a universal practice. The other message of Project Clearwater was that more Americans must change their wasteful attitude for one of stewardship.

Sponsors of the field day are quick to concede that the average farmer may not need all the practices installed on the Roelkey farm—certainly not immediately. "But if they go home and improve just one aspect of their operation, we'll have succeeded," says Poole. ■



Visitors aboard hay wagons stopped at 13 different stations for explanation of the conservation practices being installed.

The main barn, built in the 19th century, was repaired and repainted by volunteers from the Farm Bureau.



Great Lakes Winter Navigation

by **Michael J. Perrini**

The greatest bodies of fresh water in the world lie between the 49th and 41st parallel on the North American Continent, offering the people of the United States and Canada unique economic and recreational advantages. These enormous fresh water seas—the Great Lakes—are interconnected by navigable channels and are linked to the oceans of the world through the St. Lawrence River.

The Great Lakes-St. Lawrence Seaway system serves the heartland of two nations and the midcontinent of North America, but currently only through a traditional eight and one-half month shipping season on the system which extends from about April 1 to December 15. Existing Federal legislation does not prohibit winter navigation. The current Season Extension Study, underway since 1971, shows the need for increased productivity of the Great Lakes-St. Lawrence Seaway system and resultant economic accrual to the nation should winter navigation be implemented. Specifically, the future direction and major goal of the program is to determine the feasibility of means of extending the navigation season on the entire Great Lakes-St. Lawrence Seaway system and the extent of Federal participation. However, for system-wide season extension to become a reality, Canadian co-participation is required.

In order to determine the feasilibity and to provide Congress with recommendations analyzing means to extend the navigation season, it is necessary to define the engineering, economic, environmental and social aspects of an operational navigation season extension. This is presently being addressed in the survey study. Much of the significant information needed for the study is being supplied by a second ongoing activity called the Demonstration Program which will conclude in late 1979 with a report to Congress. The basic purpose of the Demonstration Program is to demonstrate the practicability of means of extending the navigation season, taking into consideration effects that such an undertaking may bring about.

Coordination and co-participation with all interests, including Canada, is of utmost importance to the development of any comprehensive system-wide program

Mr. Perrini is the Public Affairs Officer, Detroit District, U.S. Army Corps of Engineers.

Aerial of Ice Boom in the St. Lawrence River

of winter navigation. In 1977, the Water Navigation Board, a multi-agency effort formed to direct the Demonstration Program, wrote the Department of State requesting U.S. coordination with the Government of Canada to secure agreement on a program of bilateral cooperation to extend the navigation season. To date the desired coordination is slow in materializing. To the fullest extent possible, the study report will incorporate known Canadian plans for winter navigation projects or programs which would affect U.S. proposals for consideration of the Congress.

Congress, fully recognizing the environmental concerns of implementation of winter navigation on the Great Lakes and St. Lawrence Seaway system, directed in the authorizing legislation that the Demonstration Program for winter navigation be carried out in cooperation with the Departments of Transportation, Commerce and Interior, the Environmental Protection Agency, the Coast Guard, the Saint Lawrence Development Corporation, affected states, and interested citizens.

Through its development, the winter navigation program has steadily evolved from a predominately engineering orientation to a comprehensive analysis of the environmental and social implications. A comprehensive environmental evaluation plan is being formulated for incorporation into the survey report recommendation that is currently being prepared, addressing year-round season extension on the entire system. The plan is being jointly proposed by Federal and state agencies, together with concerned public organizations.

To date a partial extension of the shipping season is feasible from both an engineering and an economic standpoint. An interim report recommending an extension to January 31, plus or minus two weeks, on the upper four Great Lakes and their connecting channels has been forwarded to the Office of Management and Budget by the Secretary of the Army, to obtain the relationship of the Chief of Engineers Report to the President's program, in advance of being transmitted by the Secretary to the Congress. The study and testing of season extension on the upper four Great Lakes to January 31 has found no overriding environmental effects that would prohibit such a program from becoming fully operational. An environmental appraisal program is being recommended in the interim report to monitor the operational activities during the first three years of operation and afford a report back to the Congress.

The promise of year-round navigation season extension involves three primary benefit areas to users of the Great Lakes navigation system. First, Great Lakes region shippers of high-valued, non-stockpiled commodities would have direct Great Lakes-overseas winter service. Transportation rate savings would result from the cost difference between direct Great Lakes service and combined least-cost alternative overland and ocean rates.

Secondly, users of bulk commodities, such as iron ore, would be able to reduce summer season stockpiling to meet winter production needs. Financing and some extra handling costs for the present method of stockpiling would be reduced.

Thirdly, the productivity of the existing Great Lakes fleet would be extended through trips in traditionally closed winter months. Use of the larger, modern, more efficient vessels would result in annual freight rate savings through retirement of economically obsolete units used for peak season needs.

In addition to the above primary benefits, productivity increases from season extension would result in secondary regional benefits to the Great Lakes area in terms of increased production, income and employment.

Preliminary indications are that the average annual savings for year-round navigation on the entire system would be $300,000,000 while average annual costs are $34,000,000. The overall benefit/cost ratio therefore would be about 6 to 1. As the study progresses and concludes, system benefits and costs will be updated and include the development of benefits and costs for season extension improvements to the overall system as well as to individual Great Lakes harbors.

Energy consumption will be investigated to determine the net increase or decrease as a result of winter waterborne movement vs. winter overland movement. The investigations will provide economic and environmental analysis on this important subject.

It should be recognized that some risks are still associated with navigation season extension, particularly during the experimental Demonstration Program. For instance, without the benefit of fully designed and constructed ice control structures, the risk of ice jamming and subsequent flooding appears likely. Similar concerns for crew safety, vessel groundings, etc., are being analyzed, addressed, and if possible, improved upon as the study progresses. The magnitude and direction of change to be recommended from the traditional navigation season will indicate whether or not system reliability has been improved or if additional precautions need to be taken.

Some of the areas that have been partially addressed and will be discussed in the final report are shipment of hazardous substances, crew and vessel safety, and vessel operating capabilities. All of the above mentioned areas need to be continually monitored until satisfactory solutions have been reached. The solving of the problems associated with transport of hazardous substances, crew and vessel safety, etc., are critical to continuance of winter navigation. Typical potential solutions being evaluated are improved vessel hulls, improved navigational aids, and significantly better crew survival gear. Long-term risk to the ecosystem is being comprehensively addressed in an environmental plan of action that will discuss the environmental studies required.

The LORAN-C radionavigation system, being implemented as part of the U.S. Department of Transportation's national plan for navigation, will be available for the Great Lakes. In addition, a mini-LORAN-C radionavigation system is planned for two critical connecting channels: the Whitefish Bay-St. Marys River area and the St. Clair River-Lake St. Clair-Detroit River reach. This mini-system is currently being tested from Whitefish Bay on Lake Superior to DeTour Passage on Lake Huron. The mini-LORAN-C system would be dependent upon agreements with the Canadian government for installation and maintenance of that part of the system in Canadian territory. Also planned are fixed RACON's (Radar transponder Beacons) and floating (ice buoys) navigation aids strategically located along the navigation channels in the St. Marys River, Straits of Mackinac, St. Clair River-Lake St. Clair-Detroit River reach, and in western Lake Erie to supplement the LORAN-C system. A precise all-weather navigation system is also being considered for the St. Lawrence River. This would be supplemented by additional fixed navigation aids and the vessel traffic control system which is currently operated jointly by the U.S. St. Lawrence Seaway Development Corporation and the Canadian St. Lawrence Seaway Authority.

During winter, U.S. Coast Guard aircraft ice reconnaissance would provide weekly coverage of ice problem areas. The National Environmental Satellite Service will supplement low-level aircraft and ground ice data with satellite photographs. The National Weather Service will provide ice and weather forecasts and advisories. Maps of expected winds and temperatures over the lakes will be made during the winter, while the National Weather Service will prepare special advisories in support of person and car ferries that cross navigation channels.

Ice, weather, and temperature data would be transmitted from a planned facility to the Ice Navigation Center to provide ice summaries, charts, and ice and weather forecasts to potential users. An automated vessel reporting system from ships in transit is also being considered. Interfacing operations of the Coast Guards of the United States and Canada would continue to be coordinated through the Ice Navigation Center and/or Rescue Coordination Center and are a key to the success of the season extension program.

Many Great Lakes ports on the system are primary ports for the shipment of limestone, coal, sand, gravel, slag and unprocessed iron ore. The handling of these commodities at the terminals is severely hampered by winter and by freezing conditions. Significant progress has been made in handling of frozen coal, however, those ports shipping other bulk commodities will not extend their season until economically feasible winter handling systems are developed. Furthermore, those ports and terminals serving the international overseas vessel traffic would be dependent upon extension of the season in the St. Lawrence River.

It has been shown by various investigators that ice retardation within the Great Lakes connecting channels can affect the water levels and flows in the system. This occurrence is an important factor in the natural water levels existing in the system. Winter navigation will disrupt the ice cover in these reaches and as a result might increase or decrease this retardation effect and, in turn, affect water levels.

Proposed Navigation Modifications

Lake Superior

Winter shipping on Lake Superior is expected to be from both U.S. and Canadian harbors to the locks at Sault Ste. Marie. U.S. harbors foreseen to have winter traffic are: Taconite, Silver Bay, and Two Harbors, Minnesota; Ashland, Wisconsin; Marquette-Presque Isle, Michigan; and Duluth-Superior, Minnesota-Wisconsin. Canadian winter shipping is expected to flow from Thunder Bay and Michipicoten, Ontario.

Evaluations of Lake Superior's U.S. harbors have indicated that air bubbler systems may be needed in each of the inner harbors—primarily along the docks and berthing areas and in turning basins. Air bubbler systems will help keep surface ice melted, making ship passage easier. Tug assistance within the harbor may also be needed.

Icebreaker assistance would be required in Lake Superior to escort vessels through the ice pack, particularly in the western and eastern ends of the lake, and to provide open tracks for vessel movement. The U.S. Coast Guard will plan the level, type and deployment of icebreakers needed to support a year-round navigation season. An automated vessel traffic reporting system, which is designed to track commercial vessels operating on the entire Great Lakes system in winter, is desirable and planned.

St. Marys River

Winter navigation on the St. Marys River is probably the most difficult in the Great Lakes portion of the system. Restricted channels, locks, and severe ice conditions will require a variety of ice control measures.

Icebreaking assistance and escort services for the entire river system are being investigated by the Coast Guard. Air bubbler systems are planned for tight turns along the St. Marys River, namely at Birch and Brush Point Angle Courses where waters from Whitefish Bay enter the river; at several angle courses of the Middle Neebish Channel, and at Lime Island Turn. Floating log ice booms at the head of Little Rapids Cut are also considered necessary to help stabilize the ice cover during vessel transit.

Operational plans would be implemented to enable continuous transportation between the mainland and the four islands (Sugar, Neebish, Lime and Drummond). Provision for an alternate mode of transportation to move people under emergency conditions is also being considered.

The formation and buildup of ice in channels adjoining the locks at Sault Ste. Marie (Soo Locks) present major obstacles to extended navigation. Alterations at lock entrances, in lock chambers, and other lock facilities would be necessary. Ice control devices at the lock entrances are needed. Other alterations being considered at the Soo Locks would be: a safety boom gate housing; additional maintenance of lock facilities; cold weather gear for the lock operators, and snow removal and ice prevention equipment for walk and work areas.

Ice navigation in channels and restricted river areas provides a constant potential for ice retardation and jamming and it is necessary to constantly monitor such potential. A water level warning system is planned for the Soo Harbor-Little Rapids Cut area. A plan to seal the Edison Sault Electric Company power plant floor to eliminate the possibility of flooding is also being investigated.

Shore erosion due to winter navigation and shore protection measures are being considered for certain areas. Alternative engineering solutions and/or mitigation measures will be developed.

Straits of Mackinac—Lake Michigan

Based on studies to date, ship tracks can best be maintained in the Straits of Mackinac by use of Coast Guard icebreakers. Vessel traffic lanes would be recommended to be closed between St. Ignace and Mackinac Island.

The Lake Michigan harbors currently foreseen to be origin or destination for winter navigation traffic are Green Bay, Port Washington and Milwaukee, Wisconsin; Chicago, Illinois; Calumet Harbor, Indiana Harbor, Burns Waterway, Gary, Indiana; and Muskegon, Ludington, and Escanaba, Michigan. Harbor studies now underway will determine the full extent of work needed to permit winter navigation for each.

Ice conditions on Lake Michigan are most severe in the northern end of the lake and U.S. Coast Guard icebreaker help is needed for ships entering this area and in harbors. The entire lake is subject to shifting ice conditions and icebreakers would be required to provide the necessary capabilities to maintain traffic flow. The level, type, and deployment of icebreaker services is the responsibility of the U.S. Coast Guard. Preliminary assessments show a need for air bubbler systems along some docking facilities, berthing areas, and navigation channels, with tugs used in the harbors to provide icebreaking services.

Proceeding further south along both the west and east shorelines of the lake, the associated harbors have periodic ice problems at docks and slips. However, these are considered minor and vessel traffic in and out of the harbor, plus inner harbor tug traffic, appears adequate to handle any problem. At the harbor entrances, shifting ice, which is moved primarily east and west across the lake by prevailing winds, does sometimes cause the harbor entrances to become jammed. Fortunately, as one proceeds further south along the lake, this problem diminishes. The accumulation of drift ice can be substantial at times and may require icebreaker assistance. Milwaukee Harbor is being considered as a mooring site for Coast Guard icebreakers working on Lake Michigan, and as such new shore and dock improvements are being considered there.

Lake Huron—Saginaw Bay

In a severe winter, the ice cover along the western shore of Lake Huron can extend out several miles. Icebreaker assistance is needed on a periodic basis. Again, the level, type, and deployment of the needed icebreaking capabilities are being investigated by the U.S. Coast Guard.

Harbors along Lake Huron which are expected to have winter operation are: Calcite, Alpena and Saginaw, Michigan, and detailed winter navigation studies for these areas are underway. Canadian ships are expected to enter Little Current and Depot Harbor, Ontario, along Georgian

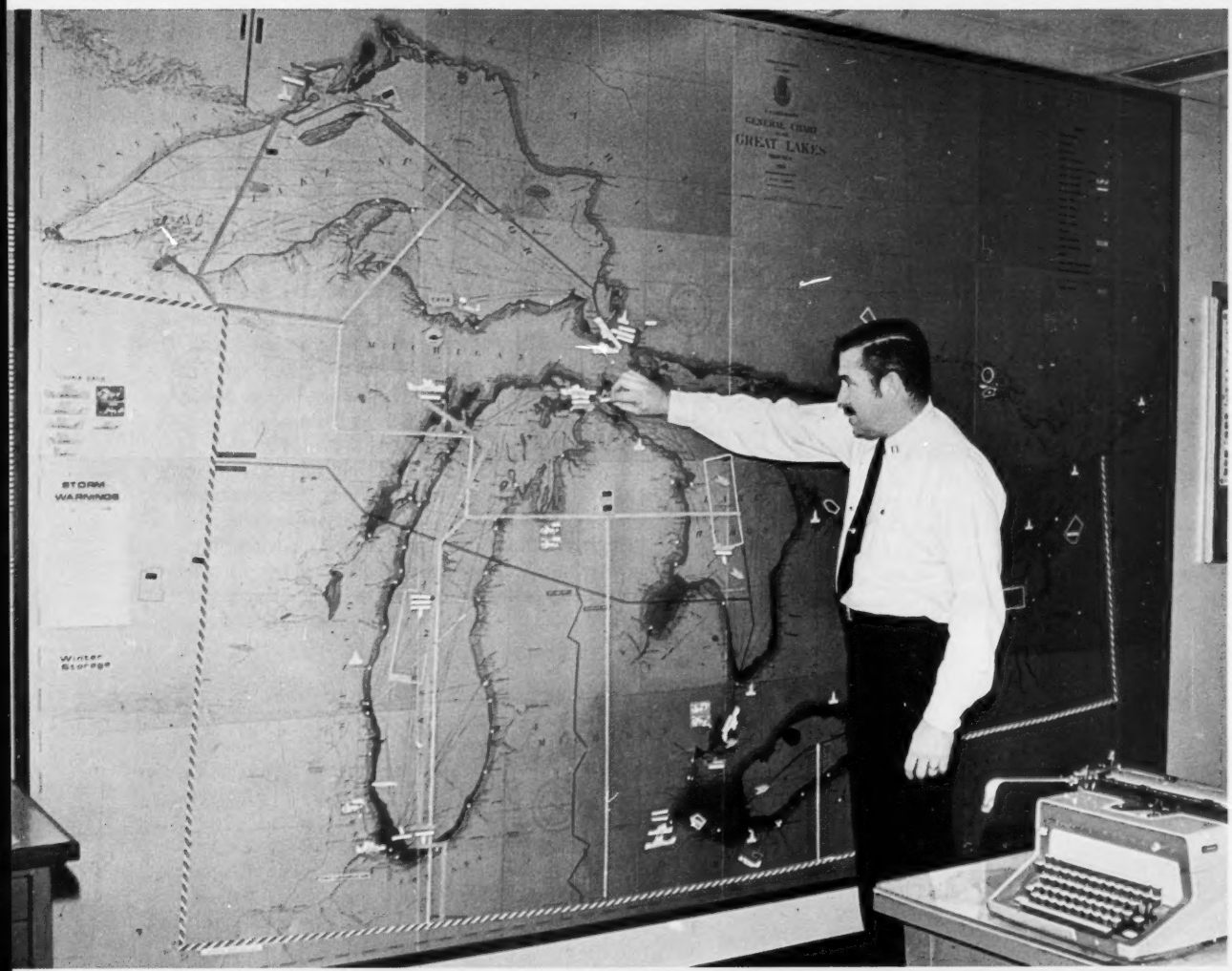
Bay, and Goderich, Ontario, along the southeastern shore of the Lake. With the exception of the Saginaw River, U.S. harbors may need air bubbler systems at the harbor dock facilities and associated channels.

St. Clair River—Lake St. Clair—Detroit River

A system study of this reach has defined several improvements considered necessary to enable year-round navigation. These improvements are: icebreaking assistance, particularly in the lower St. Clair River, Lake St. Clair and the lower Detroit River; an ice control structure (possibly a floating structure or a more permanent structure such as a series of interconnected caissons) at the head of the St. Clair River, to contain ice in Lake Huron. This would reduce significantly the present winter problem of ice flow or ice accumulation in the lower St. Clair River. An ice control structure at the head of the Detroit River, much like that considered at the head of the St. Clair River; and shore erosion and shore structure protection, particularly along the delta region of the lower St. Clair River are being considered.

U.S. harbors along this reach expecting winter navigation are: St. Claire, Detroit, Dearborn/River Rouge,

Ice Navigation Center, U.S. Coast Guard Headquarters, 9th District Cleveland, Ohio



Close-up of Bubbler System at Sugar Island Ferry Dock and the St. Marys River.

Ecorse and Trenton, Michigan. Canadian harbors are: Sarnia, Courtright, Sombra, Port Lambton and Windsor, Ontario. Detailed studies have been conducted for Detroit and preliminary assessments for the other U.S. anchorages. Original estimates are that no harbor improvements are considered necessary to enable year-round navigation.

Lake Erie

Most of Lake Erie, since it is the shallowest of the lakes, is likely to freeze completely over during the winter months. Navigation is primarily from the upper lakes into the harbors located along the south shore of the lake. Icebreaking assistance and escort service are considered essential on both ends of Lake Erie to maintain a broken ice track to Toledo, Monroe Harbor and into Detroit to and through Pelee Passage, and to keep the main navigation channel ice track open.

Shifting ice conditions are a major problem on Lake Erie, particularly along the south shore harbor entrances and in the eastern and western portions of the lake. Because of the lake's shallowness, navigation, especially on the eastern end, can be very difficult during the spring breakup period when the ice turns to slush. Icebreakers and high-powered vessels can have considerable difficulty moving in these conditions. The necessary icebreaking requirement for this reach is currently being determined by the U.S. Coast Guard.

The U.S. ports on Lake Erie foreseen to have winter navigation traffic are Monroe, Michigan; Toledo, Sandusky, Huron, Lorain, Cleveland, Ashtabula and Conneaut, Ohio; Erie, Pennsylvania; and Buffalo, New York. Canadian harbors are Nanticoke and Port Colborne, Ontario.

Welland Canal

The Canadian Welland Canal, which provides the deep draft navigation connection between Lake Erie and Lake Ontario, includes a series of eight locks interconnected by a deep draft (27-foot) waterway. Winter navigation improvements are being weighed by Canada for this facility.

Lake Ontario—St. Lawrence River

Lake Ontario is relatively ice free during most winters with the exception of the eastern one-quarter, where the prevailing winds and shallow depths combine to produce chunks of significant floating ice. Navigation would be primarily along the lake between the eastern end of the Welland Canal at Port Weller and the head of the St. Lawrence River at Tibbets Point. Improvements for the U.S. harbors, if any, will be identified in the future study.

Vessel capability criteria is proposed as a condition of winter operations through the St. Lawrence River. This is to insure that only those vessels capable of safe and efficient operation in winter weather and ice conditions transit the St. Lawrence Seaway system.

Icebreaking services will be provided by U.S. and Canadian Coast Guard vessels and supported by tugs owned by the two seaway activities. Air cushion bows, self-propelled air cushion vehicles and special channel clearing craft are also being studied for winter use.

Structural improvements such as ice booms with navigation gaps and dredging in critical reaches to reduce flow to help develop a stable ice cover are being proposed in both the Canadian and U.S. portions in the international section of the St. Lawrence River. These improvements would appear to permit a four to six-week extension of the current St. Lawrence River navigation season.

The reality of year-round navigation on these great fresh water seas and their vital link (the St. Lawrence River) to the oceans of the world depends on many factors including a satisfactory cost/benefit ratio, acceptability to the Congress and the Administration, as little disturbance to the natural environment as possible, the well-being of the people of this rich and unique area and the nation, as well as international agreement between the governments of Canada and the United States. ■

energy from the oceans

by **Bennett Silverstein**

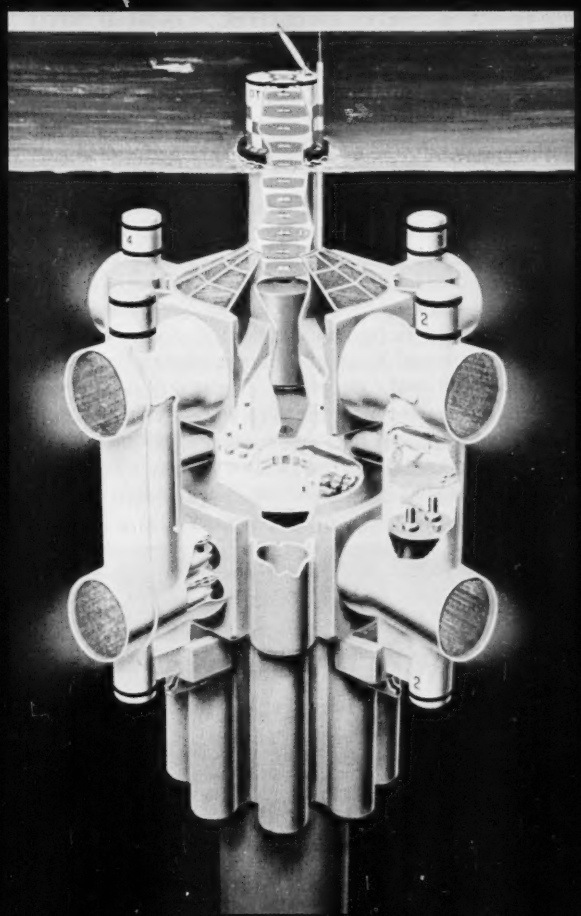


Figure 4. Lockheed System.

Dr. Silverstein is with the Oceans Program Staff, Office of Technology Assessment.

For almost a century theorists have been fascinated by the possibility of harvesting millions of kilowatts of power from tropical waters using Ocean Thermal Energy Conversion (OTEC) techniques. On paper, these OTEC systems make use of the temperature difference between deep, cold ocean waters and the warmer surface waters to run a turbine. Some pilot OTEC models have been attempted over the years with mixed success; none has ever generated a net energy surplus. The potential energy payoff is great enough, though, that the U.S. Department of Energy (DOE) is providing OTEC research and development funds of approximately $35 million this fiscal year.

If levels of funding can be said to equate to levels of interest, then the DOE must take this potential energy source very seriously, indeed. Ten times as much R&D research grant money is going to OTEC this year than has been allotted to all other (non-biomass) renewable ocean energy sources including waves, ocean winds, tides and currents.

Are OTEC systems really technically feasible? What are the key unresolved problems? Could we build a system today which would work well enough to attract private investors? How reliable would an OTEC system be in its hostile marine environment and how long would it last?

Nobody knows for sure. DOE anticipates spending about $200 million over the next five years to provide some tentative answers. This includes plans for one large pilot operation. Commercial applications of OTEC probably will not be feasible during this century, according to a May 1976 analysis by the Congressional Office of Technology Assessment. Still, the large amounts of untapped ocean energy are attractive enough to warrant OTEC research.

The ocean's surface is heated by the sun while deeper waters stay cold. The seas, covering more than 70 percent of our planet, store enormous amounts of solar energy—one estimate puts the amount at 10 megawatts. Also, ocean thermal energy is stored and available for extraction around the clock. Supplies are more reliable than direct solar collection as they can be tapped even at night or in overcast weather. It is well worth some hard study to withdraw even a tiny fraction of this stored energy.

Fig. 1 shows a generic OTEC. Warm water is drawn in from near the surface, with cold water pumped up from the deeps via a long pipe. Two basic types of heat engines are being studied for OTEC.

The leading contender is the "closed-system" type (Fig. 2). Here, a contained liquid working fluid, such as ammonia, is partially vaporized, and the vapor then expanded through a turbine to generate power. The vapor is cooled again to a liquid by the upwelled, cold, deep water and the cycle begins anew.

The alternative "open-cycle" system (Fig. 3) uses warm, surface seawater both as a heat source and working fluid. Surface water is pumped into a low-pressure chamber of about .5 psig. A small percentage flashes into steam which is expanded through a turbine to generate power. Additionally, the expanded steam may be condensed into fresh water in a condenser cooled by brine.

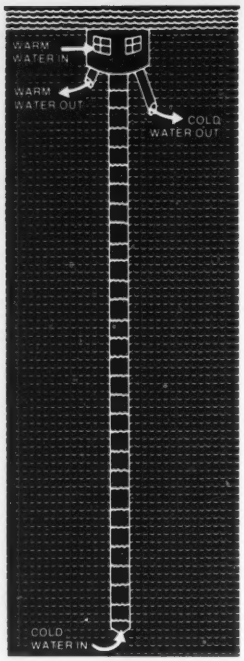


Figure 1.
A Generic OTEC Plant (Illustrations herein are from "Renewable Ocean Energy Sources, Part 1, Ocean Thermal Energy Conversion," Office of Technology Assessment Report.

If fresh water is not needed, the system hardware costs can be considerably reduced by injecting the steam directly into the cold, deep water.

In principle, OTEC is simple and straightforward. Its thermodynamics operate on the well-known Rankine cycle (similar to the cooling system of a refrigerator). Also, temperatures are favorably low compared to high-temperature gas turbines. Special heat resistant alloys are not needed for OTEC. The ocean's weather and salt environment are admittedly harsher than found on land, but for over a hundred years ships have used the seawater as the coolant fluid in condensers.

Why have we not seen OTEC systems in the past? Will there be OTECs in the future? The answers to these questions may be found in the history and analysis of the technical development and economic competitiveness of OTEC. When everything is added up, government and private industry perception of the OTEC potential may prove to be the single most critical factor in OTEC progress and support.

Use of ocean thermal energy seems to have been originally proposed in the late 1800s by Jacques D'Arsonval, although little was done until the 1920s when Georges Claude, a Frenchman, built and operated the first OTEC in Matanzas Bay, Cuba. Claude used an open-cycle system, and deliberately chose an oversized cold water pipe, recognizing that a large pipe would be necessary for future, practical OTEC systems. Instead of the desired 60KW, Claude's system had an output of 22 KW using a temperature difference of about 25° F. Unfortunately, it required 88 KW to run the auxiliary equipment. Claude had further difficulties with attachment to the cold water pipe. In fact, the loss of the pipe (first in a hurricane, and in the end, dropped from the test ship) wiped out Claude's final attempts along with all his money.

The French government renewed its interest in OTEC during the early 1940s, and concentrated on improving the ocean engineering aspects of Claude's work. The French company "Energie Des Mers" modified Claude's design to a system that was hoped could develop net power of about 7 MW.

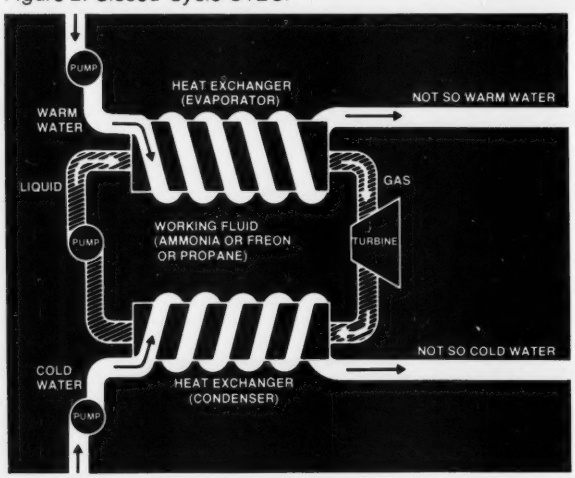
The components of the system were carefully designed and in some cases even built and tested. The critical need to extract air from the warm surface water was recognized here and a special deaerator was designed. Standard procedures for construction and deployment of the bottom-resting cold water pipe were created. The first unit was slated to be emplaced off the Ivory Coast, with future projects planned in a number of locations off South American cities. A number of firms submitted bids for the various components, but the project fell through when it became obvious that OTEC was an expensive way to generate power. Estimated capital costs exceeded those for coal or oil-fired power plants by a factor of five to ten. A further French modification was made for possible installation in Guadeloupe, where fresh water was a key output. Various local problems were burdensome, including rough ocean bottoms, high seasonal variations in available temperature difference, and cool, not cold, water at substantial water depths. The economics were again unfavorable. These experiences appeared to have soured the French on development of OTEC.

The University of California at Berkeley, though, began studying the Claude process as a possible means of demineralizing seawater. A number of laboratory tests were conducted including the installation of a single-stage turbine to develop some power. The system worked, but apparently the cost of making freshwater was too great, and the project ended in the late 1950s.

The Andersons (J. Hilbert and James) again sparked interest in OTEC in 1966. They proposed a closed-cycle concept to develop about 100 MW. A sketch of this idea (Fig. 3) was offered by the Andersons' Sea Solar Power, Inc. Soon after, Hernoemous at the University of Massachusetts and Zener of Carnegie-Mellon University prepared additional concepts.

Additionally, the early French studies are the basis of Roels' investigations into combining mariculture with OTEC. The bottom cold water is nutrient-rich, and could be used to produce phytoplankton, which in turn could

Figure 2. Closed-Cycle OTEC.



provide food for raising shellfish. Since, in any case, the cold water has to be raised for the OTEC, this combined system might generate electricity, fresh water and an increased fishery. Roels envisions a small (in the order of a megawatt) land-based OTEC.

Since then, more detailed OTEC designs have been prepared. Examples are the Lockheed (Fig. 4), TRW (Fig. 5) and the Johns Hopkins Applied Physics Laboratory (Fig. 6). All three used closed-cycle systems. Table 1 summarizes some of the dimensions and characteristics of these three designs.

The Lockheed and TRW designs generated electricity but were not configured for any particular site and did not consider transmission of the electricity to a customer. The Johns Hopkins system was designed to manufacture ammonia, 300 miles off the east coast of Brazil, and barge this product to the United States.

The mother lode of OTEC energy is within ± 20° of the equator. Scientists have collected data on ocean areas that have high average temperature differences using water depths of 1000 meters. Some observations may be made:

- There are virtually no good sites near industrialized countries. Europe and Japan have no nearby useful OTEC locations.
- The United States has a limited number of good sites. These seem to be near Puerto Rico, Hawaii and some parts of the Gulf of Mexico.
- The best locations are on the high seas, off central Africa and eastern South America.

Another map has been prepared for the Department of Energy depicting OTEC sites where the cold water is obtained at water depths of 500 meters. Then, the areas having average temperature differences of 20°C are enormously reduced. A fairly large area in the central and Far Eastern portion of the Pacific Ocean is satisfactory, but the only other suitable sites are a small area west of Mexico, and a somewhat larger area off Brazil extending eastward toward Africa.

A number of criteria can be set up by which to evaluate good sites for OTEC. These are: High thermal differences year round between the warm surface and cold, deep water; the cold, deep water should not be unreachably deep; low-velocity currents; minimal winds and waves; and closeness to markets for the OTEC products. Exact criteria, e.g. how many knots constitute "low-velocity," are needed.

Since criteria are not quantified, trade-offs in a particular design are necessary. Some quantities, though, are worth mentioning:

- An average thermal difference of at least about 20°C is desirable.
- The cold, deep water should be about 5°C at a depth of 500 meters but not more than 1000 meters.
- The power required for dynamic positioning increases at a greater rate than the cube of the current velocity. A reasonable rule of thumb is that the current should be less than one knot, but not dead calm.
- Hurricane areas should be avoided.
- Transmission cables from an OTEC to a grid can be very expensive. Costs of a million dollars and more a mile are quoted. More than 100 miles offshore is therefore not attractive. If the OTEC is manufacturing a product, the further from the market, the more product vehicles are needed and the higher the transportation costs.
- If OTEC systems prove to be desirable, the good sites will attract competition. Foreign competition has proven to be very successful in shipping and OTECs within a nation's own waters could be protected from foreign ventures.

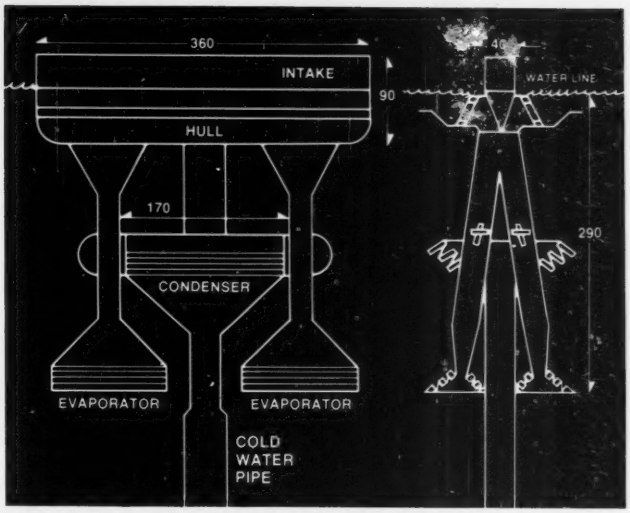


Figure 3. The Anderson Concept (OPEN CYCLE).

These generalizations about OTEC sites give some insight, but the "moment of truth" occurs with the selection of a particular OTEC system, emplaced in a definite ocean location, and manufacturing and marketing an explicit product.

Claude's work showed that an OTEC could develop power. The Andersons built a small demonstrator of a few watts which operated with hot tap water and cold tap water augmented by ice cubes. The University of California laboratory tests generated a couple of kilowatts. No OTEC system has ever been built and operated that generated more power than was put in to run the OTEC equipment.

The major troublesome technical problems stem from two sources: OTEC systems will operate at low efficiencies and they must perform reliably in harsh ocean environments.

The Carnot cycle efficiency of an OTEC is at best about 7 percent. Actual operating efficiencies will be between 1 and 2 percent, compared with a fossil fuel or nuclear plant

Table 1	Lockheed	TRW	Johns Hopkins/APL
Power (MW)	160	100	100
Type	Spar-buoy	Disk	Barge
Material	Concrete	Concrete	Concrete
Height (feet)	592	170	129
Draft (feet)	532	110	85
Length (feet)	400	340	476
Beam (feet)	246	340	136
Displacement (long tons)	355,000	213,500	66,000

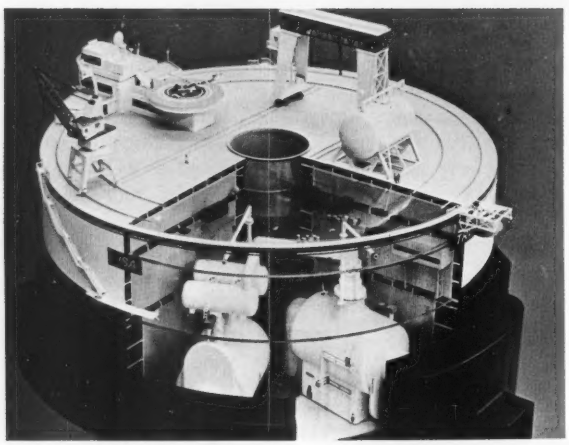


Figure 5. TRW System.

which operates at better than 30% and as high as 42%. This does not mean that if an OTEC pump designed for 90% efficiency operates actually at 85% there will be no net output of power. It does mean that great care must be taken to minimize parasitic losses. Some of the more detailed designs include the estimate that between 20 and 40 percent of the gross power output will be needed to run the auxiliary systems. Very careful trade-offs will be needed, for example, to size the cold water pipe. A half-dozen small diameter pipes could provide the water flux needed just as well as one large diameter pipe, and perhaps at less initial cost. The multi-pipe system, however, requires considerably more auxiliary pumping power.

The major effect of low efficiency is that OTEC systems must be large and process enormous quantities of water. For example a 100 MW OTEC will move 30,000 cubic feet of water every second through its evaporators and condensers—more than two and one-half times the flow of the Potomac River at Washington, D.C.

The large OTEC system is exemplified by the Lockheed design, where Table 1 shows their 160 MW plant to be the size (displacement) of a supertanker.
The technical problems are of varying degrees of engineering difficulty, the most difficult involving the heat exchangers and the cold water pipe.

The heat exchangers of the closed cycle OTEC plants are the most expensive single components. About half the initial cost can be ascribed to the heat exchangers. The heat transfer must be efficient and cannot be degraded with time. The primary concerns thus deal with the selection of materials, biofouling (and its removal), corrosion and construction techniques.

A number of important results have been produced by research to date. In single tubes and small bundles, excellent heat transfer coefficients have been measured. Also on a small scale, slime attached at a fairly slow rate and was cleaned by simple mechanical means. Scale-up to a million-tube system, is, however, not trivial.

It is not yet clear what material is best suited for OTEC heat exchangers. All the candidates have significant pros and cons. The apparently best technical solution (titanium) might be too expensive and not available in large quantities. A favored alternate, aluminum, might not have a long enough life. Copper-nickel is the proven alloy in almost all shipboard condensers but it is not compatible with ammonia, the leading candidate for the working fluid. In addition, an enormous copper-nickel heat exchanger could leach out large quantities of copper ions that are lethal to the local marine biota.

There is also no consensus on the type and construction techniques for the heat exchangers. Shell-and-tube is state-of-the-art, but expensive. Plate-and-fin types have never been constructed approaching the size needed in an OTEC. Cleaning of slime and corrosion products of plate-and-fin types needs research.

Ammonia is the leading contender for the working fluid of closed-cycle OTEC. It has high conductivity and a large heat capacity. This leads to relatively smaller heat exchangers than for other working fluids. But if oil or dirt accumulates on the heat transfer surfaces, ammonia will not clean them so well as, for instance, freon. An ammonia leak would cause catastrophic corrosion of copper-nickel. There also seems to be a compatability problem with aluminum. A leakage of freon into the atmosphere, and eventually up to the ozone layer might be environmentally unacceptable.

Some OTEC dimensions are simply huge. A large OTEC might require a pipe that is more than a hundred feet in diameter and perhaps greater than 3,000 feet long. This is a unique engineering problem. The pipe might be three times the length of the Empire State Building and more than twice the diameter of the Baltimore Harbor Tunnel. Some similarity exists with Shell Oil's SPAR 1, an oil storage and production platform which is over five hundred feet long and measures about 100 feet at its largest diameter.

The cold water pipe will likely be attached to the OTEC platform. Winds and waves would likely excite the platform into motion and the resultant loads and stresses are considerable. The latest studies indicate that relief of the bending stresses is essential. Flexible material or many

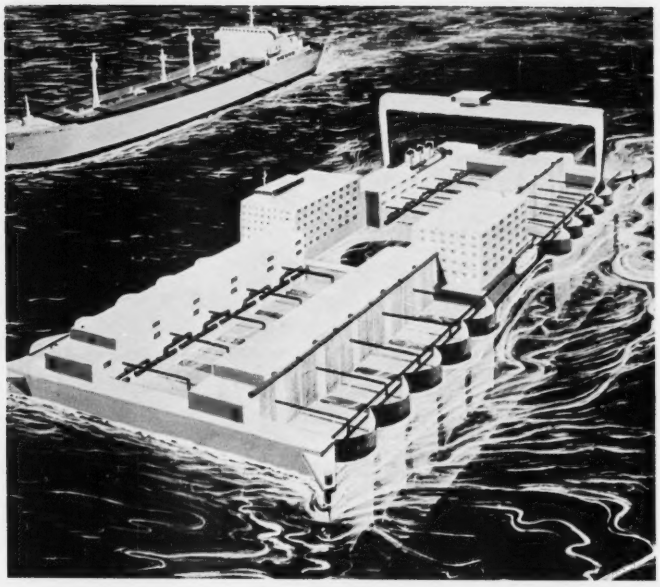


Figure 6. Johns Hopkins Applied Physics Laboratory System.

flexible joints are needed, but no experience exists with flexible joints in large, underwater concrete construction. Existing design tools for the substantial undertaking are suspect and large-scale testing may be needed.

Furthermore, a large diameter cold water pipe will generate large drag and oscillating forces in currents. This could make for expensive or even infeasible dynamic positioning systems and will certainly affect any proposed mooring systems.

In summary, it appears that OTECs are technically feasible. A system can be built to generate power from differences in ocean temperatures. No fatal technical flaw has yet appeared that disqualifies OTEC as a potential energy source, but there are no applicable data to assess the reliability of any given system or to gauge expected life. We do not know what to expect.

Even if it passes its engineering hurdles, OTEC must prove advantageous on an economic basis.

At this stage of OTEC development the economic data are necessarily very incomplete. There is as yet no detailed design for a particular site nor a system to produce a specific product. By contrast, coal and nuclear plants run between $600 and $1,200 per KW, and 20 to 50 mills/KWH. Various estimates have been made for different OTEC designs, with the range of capital costs in the literature about $500 to $4,000 per kilowatt. Even the most optimistic concede that $500/KW is no longer reasonable. Some skeptics, however, see OTEC costs exceeding $10,000/KW.

Operating costs are even more uncertain since they depend upon such unknown factors as capital cost, capacity factor, fixed charge rate, and cost of maintenance. One set of calculations yields a range of operating cost that may be betweeen 16 and 126 mills/KWH. The truth is no one knows.

Various studies have been made as to appropriate missions for OTEC. The Department of Energy staff is most hopeful about generating electricity and transmitting it in a grid in the United States. The Applied Physics Laboratory favors the manufacture of ammonia. Under contracts to DOE, dozens of studies have been made—including the possibilities of gasifying coal, storing the energy in batteries, transporting the heat in hot rocks and making methanol. The Office of Technology Assessment analyzed the prospects for electricity, ammonia and aluminum, and for various reasons, it was found that none of these OTEC products made economic sense today or in the near future. This could, of course, turn around if the technical problems are solved by less expensive components, or if the cost of alternative fuels such as coal, gas, oil and nuclear rise sharply.

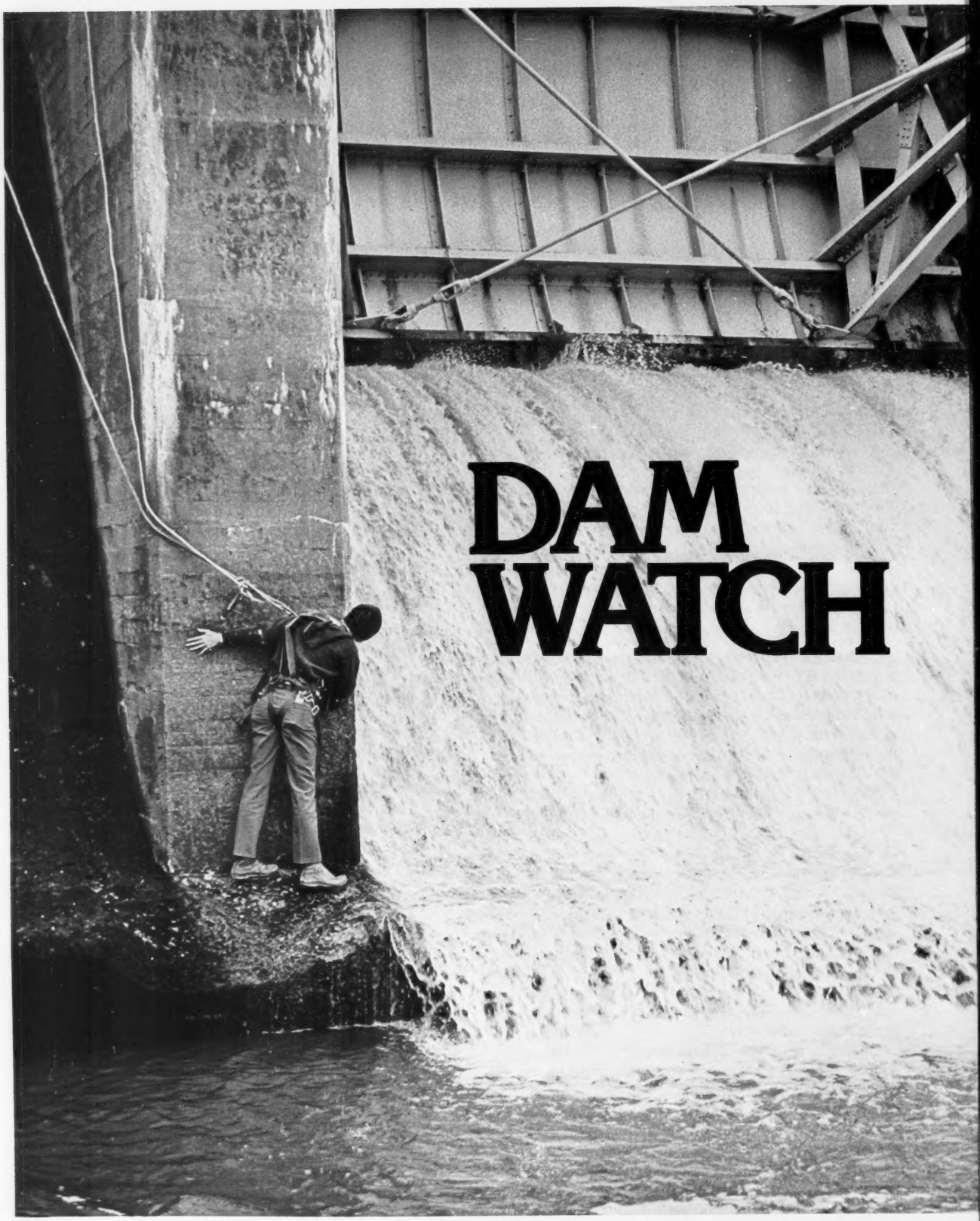
Is there an OTEC in your future? Not anytime soon. The various systems still have major unsolved technological problems and OTEC is still an expensive way to generate electricity or power an ammonia factory.

But do not brush OTEC aside, either. As I noted, supporters of this ocean energy source have already won a significant battle in getting and holding the attention of federal research and development grantors. The federal grant money should result in a pilot OTEC plant by the late 1980s. It is at this pilot stage that we can begin to get a real feel for what to expect from OTEC. ■

OTEC-1, the nation's first floating ocean thermal test platform, will be designed and built by Global Marine Development Company, Newport Beach, CA, under a recently awarded DOE contract. TRW, Inc., of Redondo Beach, CA, will act as subcontractor.

Tests on board OTEC-1 will initially concentrate on thermal performance of heat exchangers and methods to inhibit and remove corrosion and biofouling. Actual testing and evaluation of the components installed on the floating test platform will be conducted by the Energy Technology Engineering Center, Canoga Park, CA, a division of Rockwell International.

The first tests using the platform are scheduled to begin in 1980.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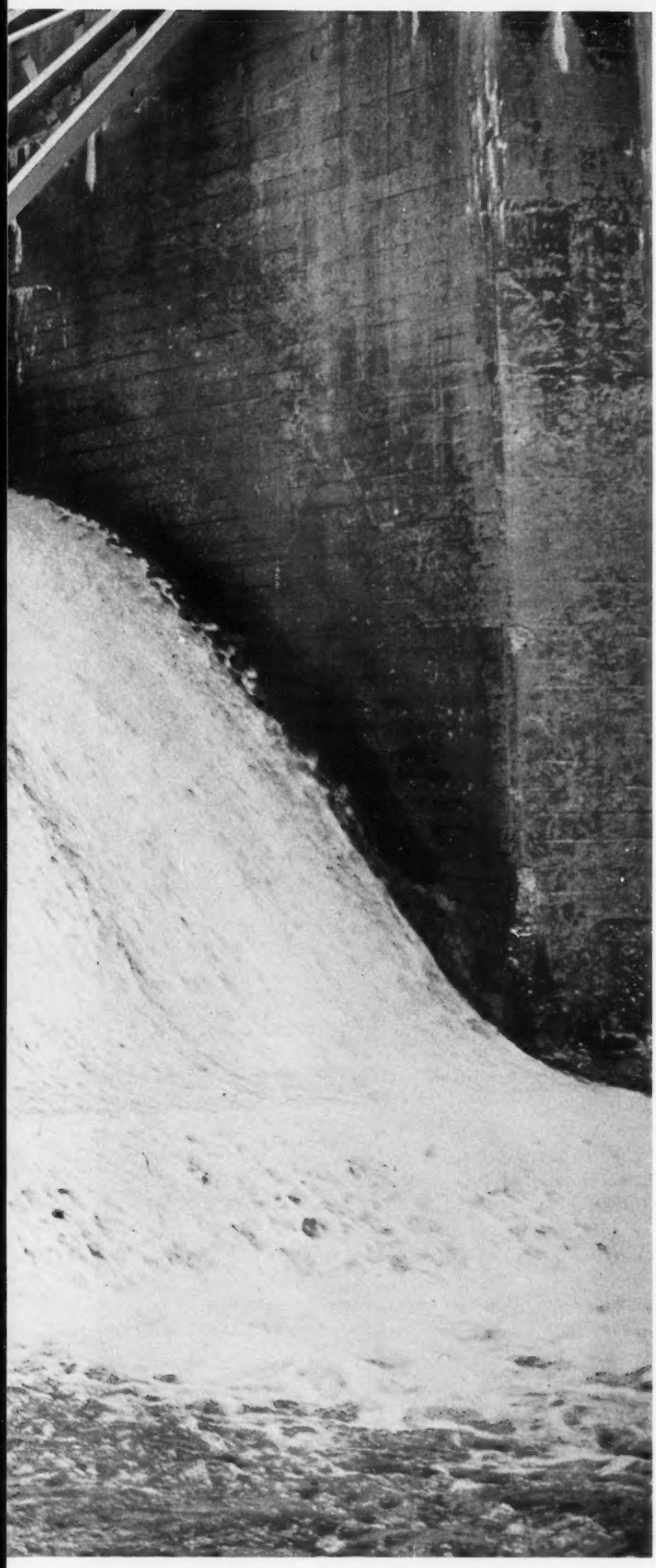

by **Ward Rinehart**

The students and staff of Toccoa Falls Bible College in Toccoa, Georgia, awoke at about 1 a.m. on November 6, 1977, to a sound one student described as just "like a tornado. You could hear the cars banging and bouncing against each other and the trees." The Kelly Barnes dam, a 40-foot high earth dam owned by the college, had collapsed under the pressure of four days of heavy rain. The water of the 30-acre lake behind the dam rushed downstream, pouring over the 183-foot Toccoa Falls, and a wall of water 30 feet high inundated the campus.

"All of a sudden the water started rising," said a student who had been watching the creek. "One minute it was inches deep and the next I was swimming for my life." In all, 39 people died. More than two dozen house trailers, several permanent dwellings, and some college maintenance buildings were destroyed. The water left a path of destruction 2.5 miles long and up to 1,500 feet wide. In terms of loss of life, it was the worst dam disaster since a coal wastebank in Buffalo Creek, West Virginia, collapsed in February 1972, releasing flood waters that killed 125 people.

Kelly Barnes was a dam built over a dam. The first structure on the site was a stone-filled timber crib 10 or 15 feet high, built at the turn of the century. By 1937, earth piled over the old structure had raised the dam's height to about 40 feet. While the dam at one time provided the college with water, electricity, and recreation, its power and water supply functions had been abandoned. In some ways, the Kelly Barnes dam was like many other small, privately owned dams throughout the country: its construction piecemeal, its design without consistency or continuity of responsibility, its design features unrecorded, some of its original uses abandoned, its inspection and maintenance at best intermittent, and its owners lacking training in the requirements of dam safety maintenance.

The Toccoa disaster spurred President Carter to revitalize the National Program for Inspection of Dams. Within a

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month of the dam failure, he announced that the Army Corps of Engineers would begin immediately to inspect more than 9,000 nonfederal dams identified as likely to cause loss of life and property should they fail.

History

The legislation authorizing dam safety inspections had been passed in response to the Buffalo Creek dam failure. While expressing misgivings about the possible costs of the program and pointing out that dam safety is a state responsibility, President Nixon signed the bill, the National Dam Inspection Act, in August 1972. The law calls for the Corps of Engineers to inspect every dam 25 feet or more in height or with the capacity to impound 50 acre-feet or more of water. Excluded are dams 6 feet or less in height or with a storage capacity of less than 15 acre-feet. Also excluded are dams whose collapse would not endanger life or property, dams under the jurisdiction of the Bureau of Reclamation and the Tennessee Valley Authority, dams inspected in the preceeding year by a state agency—if the governor requests their exclusion, and dams under the jurisdiction of the International Boundary and Water Commission or constructed under Federal Power Commission licenses—unless the agency involved requests the Corps' help. The statute also calls on the Corps to inventory all dams in the United States that meet the size criteria.

Despite the language of the Act, the Nixon and Ford Administrations never approved funding to carry out actual inspections. On the grounds that dam safety is a state responsibility, the program was limited to the inventory and to preparation of a proposal for a national dam safety program. Congressional interest shifted to other matters, and no money was budgeted for inspections until mid-1977, when, responding to the failure of the Bureau of Reclamation's Teton Dam in Idaho, Congress voted $15 million for the program.

The dams were inventoried in 1972-1976. Some 49,329 dams were counted in the states and four territories. A massive, five-volume record published by the Corps lists each dam by name, type of construction, year of completion, purposes, height and maximum storage capacity, the river or stream on which it is located, the name, population and distance from the dam of the nearest downstream community, the owner's name, and the dam's location by Congressional district. In addition, information was available to place more than three-quarters of the dams in one of three classes according to the potential for damage and injury downstream should the dam fail to be improperly operated. Half of all the dams inventoried had low potential for damage, 15 percent had a significant hazard potential, and 11 percent, or approximately 9,000 (including the Kelly Barnes dam), had high damage potential.

The classification of dams by hazard potential has nothing to do with the structural integrity of a dams and was not based on any inspections of structures. The rating depended only on the degree of development downstream that could be flooded if the dam broke, and it serves to determine the priority for the actual inspections now going on. The 9,000 so-called "high hazard" dams are those being inspected first. Also to be inspected are "significant hazard" privately-owned dams located on Federal property and other dams that state officials think may pose immediate threats to public safety.

A survey of state capabilities, practices, and regulations for dam safety, conducted by the Corps along with its inventory of dams, disclosed that most states either have insufficient legislative authority over dams or lack the funds to carry out the program already on the statute books. All 50 states plus 3 territories answered the survey. Some 11 of them had no dam safety laws of any kind, and 24 said their laws were inadequate for their needs. Twenty states said they planned to upgrade their regulations. There were 18 states with no inspection program, accounting for 19,000 dams.

Most states—41, according to the Corps' survey—require a construction license or permit to build a dam. That, at least, allows the state to keep track of the location and original ownership of dams. Some 36 states told the Corps that they review plans and specifications before construction, and 23 said they send state employees to inspect dams during construction. But, while 32 states had the authority to inspect dams after construction, in fact continuing inspections were rare, due chiefly to lack of funds and personnel. With over 54,000 dams under state jurisdiction (including those too small to be included in the Corps' inventory), the approximate total state expenditures for dam and reservoir supervision were only $4.3 million a year, or about $80 per dam.

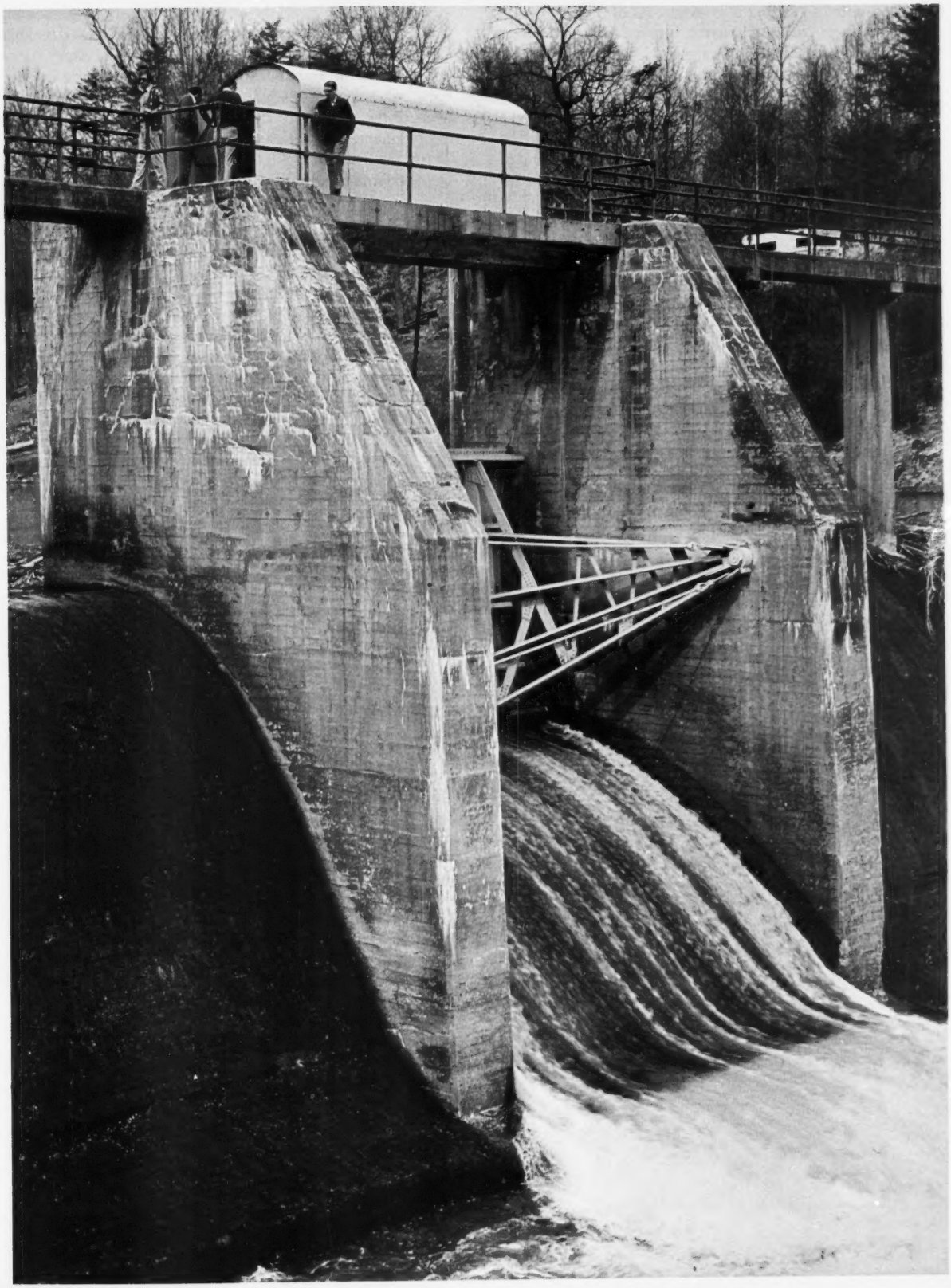
Among inspection programs, California's, established by statute in 1929, is often cited as exemplary. It includes annual inspections by state-employed inspectors. The dam owner pays a licensing fee for the dam and an inspection fee, but they are nominal; most of the program's cost is borne by the taxpayers. At the other extreme is Maine's safety program, where a single dam inspector receives $5 a day for his work—the amount specified by the 1875 legislation that established his position. As a result, dam inspection is a weekend job for a city engineer, and he inspects a dam only when ten or more people petition for it.

State Involvement

The Federal program now underway provides for the Corps or its contractors to conduct initial inspections only, and then only where states are unable or unwilling to perform the inspections themselves. Since dam safety is a state responsibility, and a continuing one, the Federal program is designed with incentives for states to take an active role. Highest priority for inspections is going to states that promise to implement and/or upgrade state dam safety legislation, involve state personnel in the Federal inspection program so they can be trained, and assure that they will take measures to deal with any hazardous conditions that are uncovered. Furthermore, after fiscal year 1978, priority for Federal funding of dam inspections depends on states' showing that they will adopt comprehensive programs for inspection of dam construction and operation.

The Corps is seeking to turn over responsibility for inspections to the states as rapidly as possible. State involvement

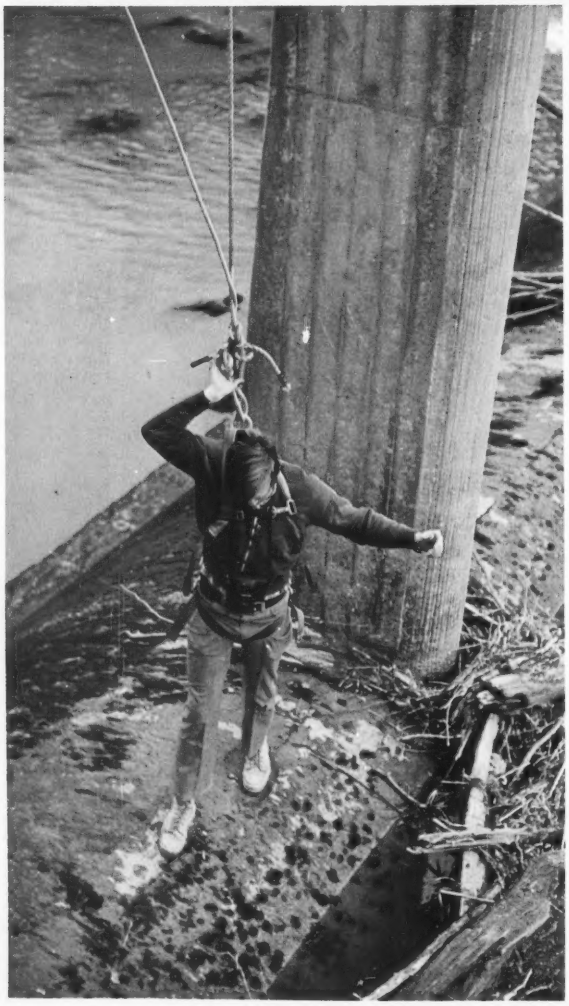
The Lake Jackson dam in Prince William County, northern Virginia, was inspected by personnel from the Army Corps of Engineers' Norfolk District, along with state and local engineers and scientists, in April 1978. Built by the Virginia Electric Power Company in 1928, the dam generated electric power until the mid-1950s. The company turned the dam over to the county in 1963. Here, the inspection team assembles at the operating equipment shed over the spillway.



has been limited so far but is growing. As of September 30, 1978, the Corps was supervising inspection in 31 states, while state officials were in charge in 19 states and Puerto Rico. (The Corps and the State of Kansas are working jointly.) The fact that the program stated in the middle of a fiscal year may explain why the states have not yet taken on a bigger role, and Corps officials hope that the program will be entirely supervised and conducted by the states by the end of the year. States that take over the work are reimbursed for their expenditures from Federal funds.

Most governors have been eager to propose and support new dam safety legislation because their commitment to developing an effective program is a prerequisite for obtaining continuing Corps assistance. The reception in state legislatures has so far been mixed, however. For example, as of early July, Mississippi and Georgia had passed and implemented new laws, but South Dakota, Missouri, and Hawaii legislatures had rejected dam safety bills. In other states—New Jersey and Delaware, for example—new legislation was awaiting votes or was scheduled for introduction in the near future.

Corps structural design engineer Jeff Irving makes his way across the crest of the dam.



While early inspections were made largely by personnel from the Corps' field district offices, as the program develops Corps personnel are limiting their role to supervisory functions, due to the amount of time required for on-site inspections. Where the states have not been willing or able to take over for the Corps, private architect/engineering or consulting engineering firms are being hired under contract to the Corps. By September 30, the inspections of 1,328 dams were under contract and inspections of over 1,300 had begun.

The Inspection Team

A dam safety inspection team is an interdisciplinary group. A typical team might be composed of a structural engineer, a soils engineer, a geologist, and a hydrologist. At the dam site, the team breaks up into small groups—a pair going to look at the toe of the dam, others inspecting the operating equipment, some walking along the banks of the impoundment. Each group looks at aspects of the dam on which it has expertise, and dividing up the team allows each group to reach its own conclusions, uninfluenced by the others.

The safety inspectors' equipment is likely to include nothing more elaborate than a camera, a folding rule, and a geologist's hammer. Suggestions of trouble will be visible to their educated eyes. The inspection team looks for signs of seepage or leaks on the face of the dam or on the banks downstream. Trees on the banks growing at odd angles may imply that the ground has shifted. Cracks in concrete and rock slides would suggest the same thing. Are drains clogged with debris? Are spillway gates deteriorating? Is the toe of a concrete structure being undermined by water? Has the downstream slope of an earth dam eroded? (Should this visual inspection prove inconclusive, additional investigation, possibly using instruments, can be conducted to help answer remaining questions, but this has rarely been necessary.)

After examining the dam, the team returns to its offices to integrate its observations with what can be learned from charts, blueprints, operating records, hydrologic data, permits, and other written records, as well as from the accounts of local people familiar with the dam's construction and its operation through the years. In many cases, inspection teams are finding that written records are scarce—particularly when the dams were built without government involvement and were constructed before 1940. Records are better in the West, the inspectors find, because dam owners have wanted to avoid disputes over water rights.

An extreme case of lack of records is a dam apparently without an owner. A 35-foot high masonry dam that impounds the 26-acre Silver Lake in a residential area above Atlanta was found on inspection to be leaking from cracks in the eroding mortar. Stability analysis indicated risk of the dam overturning. With a residential subdivision immediately downstream, the situation was obviously an emergency. The Corps' Mobile District, using pumps, lowered the reservoir about 18 feet, and later the dam was breached. But, through all this, no owner of the dam could be identified. Now questions arise: should the dam be rebuilt, as the neighborhood wants, and, if so, who should do it?

An inspection team's report assessing the condition of a dam is sent to the Corps District Engineer for his approval. Once he okays the report, he sends copies to the state's

The force of flood waters from the collapse of Kelly Barnes dam crushed this automobile against a tree. Behind the auto is a building foundation, but the building itself is gone.

governor and the dam's owner simultaneously. Since dam safety is a state responsibility, public announcements about individual dams and planning for dealing with unsafe conditions are handled by state officials.

As of September 30, some 2,099 inspections had been initiated, 1,793 reports had been completed and turned over to the District Engineers for review and approval, and 1,107 reports had been approved and furnished to governors and dam owners. Some 189 dams had been reported unsafe. These statistics do not necessarily mean that nearly ten percent of the nonfederal dams in the country may be unsafe. The proportion may be high because the inspection teams have gone first to dams where unsafe conditions were suspected. Moreover, a report that a dam may be unsafe does not necessarily imply that drastic and immediate measures are necessary. While 19 dams have been breached or at least partially drained because they appeared to be so hazardous that they required immediate action, in most cases quick attention to repairs is sufficient. For example, an inspection team found that a dam in Anderson County, South Carolina, had a badly deteriorated wooden tainter gate on its spillway. Lowering the reservoir to the spillway crest and repairing the gate was all that was necessary to restore the dam to a safe condition.

With only 189 unsafe dams detected so far, no patterns have appeared that would help direct the further search. The unsafe dams have been new as well as old. In Nebraska, an inspection team found signs of problems in an earth dam even as it was being filled for the first time. (The well-known 1976 failure of the 405-foot Teton Dam in Idaho occurred during initial filling. See photos.) In Tennessee, a new earth dam was declared unsafe while it was still dry. Cracking had appeared on the dam crest, there were slides on the upstream face of the embankment, and the outlet pipe was too small. As with age, no patterns have yet appeared in the symptoms that unsafe dams exhibit, although so far excessive seepage seems to be a frequent problem.

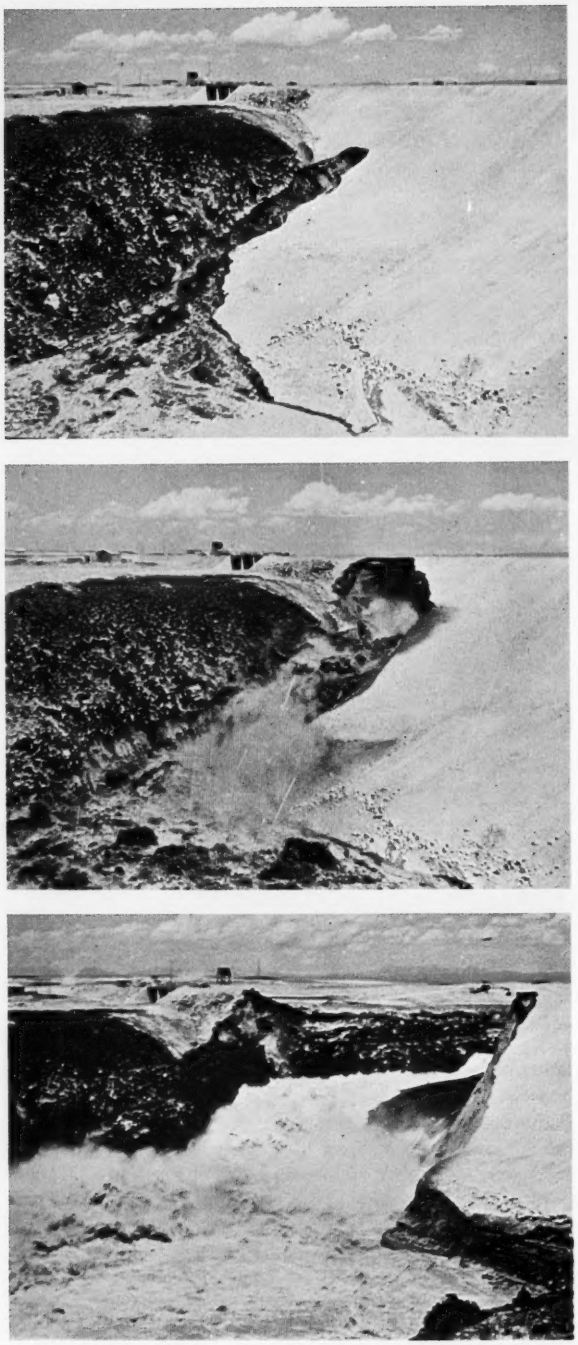
The standards for dam design have risen over the years, creating a question for the inspection program. Currently accepted criteria are set forth in a publication entitled *Recommended Guidelines for Safety Inspection of Dams*, prepared by the Corps with the help of other Federal agencies, state agencies, professional engineering organizations, and private engineers and thus expressing the consensus of the engineering profession. According to the *Guidelines*, which serves as the handbook for the inspection program, a small dam with low hazard potential should be able to handle at least the 50-year flood—that is, the flood that, on the average, occurs only once every 50 years. Standards are more stringent for larger dams with greater hazard potential. The spillway of a small dam of high potential should be designed for at least half the probable maximum flood, as determined from National Oceanographic and Atmospheric Administration estimates of probable maximum precipitation for the watershed. Intermediate and large dams of the high hazard category should be able to handle the probable maximum flood. However, very few nonfederal dams were designed with spillway capacity sufficient to meet the *Guidelines* recommendations. Should all these dams be declared unsafe?

The fact that water may overtop a dam in a severe flood does not mean it is necessarily unsafe, of course. While failure of a dam may increase damage downstream, the danger lies chiefly in the flood. Thus, inspection teams are informing governors when they find a structure with seriously inadequate spillway capacity if (1) there is high potential for loss of life from flooding downstream, (2) the spillway could not handle half the probable maximum flood without overtopping and causing the dam to fail, and (3) failure resulting from overtopping would significantly increase the potential for loss of life downstream over that attributable to the flood itself without dam failure.

Corps officials originally estimated that a single inspection would cost about $7,500 on the average. As of September 30, costs were averaging about $1,000 above the estimate, with a range from $6,900 to $12,900 per dam. At $8,500 a dam, the program's $15 million FY 1978 appropriation would have covered the inspection of 1,500 dams. Transfer of funds from surpluses in other accounts and supplemental appropriations to provide an additional $3 million were approved by the Congress's public works committees in June. As architect/engineer firms and state inspectors become more familiar with the work, average cost per inspection is expected to drop slightly. The FY 1979 budget contains $25 million for the program; the inspection of 2,443 dams is planned. Over its four-year lifetime, the program may cost $80 to $90 million.

States which establish programs for periodic inspections can anticipate much lower average costs than the initial inspection program is encountering. This is because, once the initial inspection is made and the records assembled, the dam inspector needs to look only for changes from previous conditions.

At the same time individual dams are being inspected, the Corps' inventory of dams is being updated and verified. Here the states are taking the lead, 34 of them and Puerto Rico having assumed supervisory responsibility for this aspect of the program. The National Aeronautics and Space Administration has developed a method for detecting and locating bodies of water using data from the earth resources satellite Landsat. Spectral reflectance data obtained from Landsat can spot bodies of water as small as five acres in surface area and often can provide hints whether the body is artificial or natural, so satellite imagery is serving as a basis for the inventory work. In preliminary studies, the number of dams that could be found by satellite exceeded the numbers estimated by state officials.



Collapse of the Teton dam: After springs had appeared downstream on the two preceeding days, a muddy flow developed at the toe of the dam at about 8:30 a.m. June 5, 1976, and a half hour later water was spotted flowing from the right abutment rock. By 10:30 a.m. a leak had developed in the face of the dam about 15 feet from the abutment, and by 10:50 it had become a sinkhole. The tunnel through the dam rapidly widened, then collapsed, creating a gully through which the water poured, carrying away the dam's earth fill and approximately 100 feet of the abutment rock.

Proposed Legislation

At the Federal level, the major concern for dam safety inspection in the future is how to encourage the states to develop adequate, on-going programs of their own. This question and others have been addressed in hearings by the Senate Subcommittee on Water Resources of the Committee on Environment and Public Works. The committee approved, and the Senate later passed on a voice vote, a bill proposed by Sen. James A. McClure (R-Id.) and others that uses Federal funds as both carrot and stick for the states. The bill would authorize the Corps to distribute to the states $15 million a year in FY 1979, 1980, and 1981. One-third would go to states with Corps-approved dam safety programs, and the rest would be divided among all states based on the number of dams per state. The bill also would authorize Federal reinsurance or guarantees for insurance companies that insured private dams. This provision is intended to see that full insurance is available to dam owners whose liability has grown due to development of the downstream area but who have not profited proportionately by that development. Federal reinsurance would be available only in states with approved dam safety programs.

The McClure bill sets out general guidelines for a state program. The states would have to review plans for new dams, conduct reviews during construction and also before filling, and then inspect the structure at least once every two years. In addition, the state would have to have the authority to require modifications or repairs of unsafe dams and to enforce their orders, to develop an emergency procedure for dam failures, and to set up a fund to pay for breaching a dam or taking other emergency measures necessary. The *Guidelines,* used in the current Federal inspection program, would not necessarily be the standard for state programs; the Senate committee suggests that states will want to tailor their programs to their own situations.

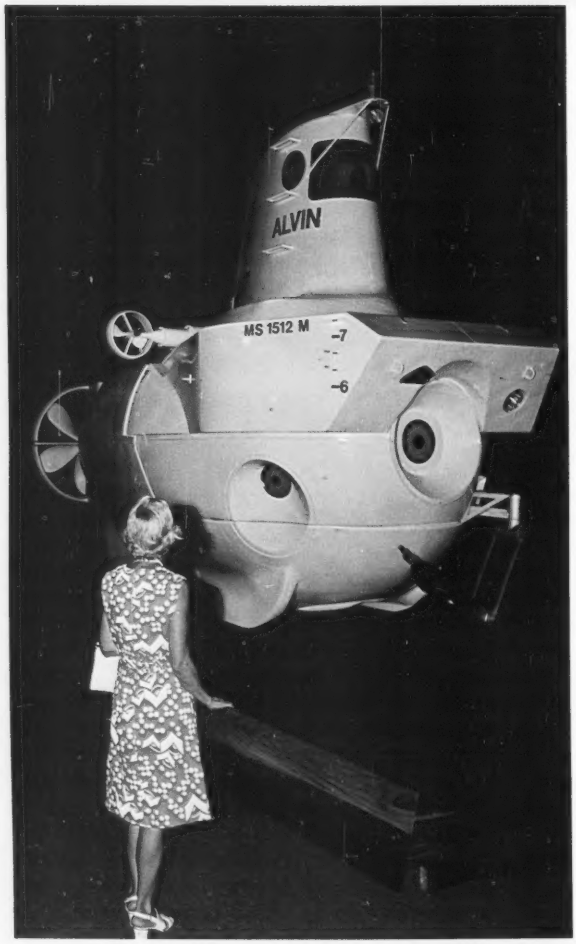
To help pay for repairs to assure dam safety, the bill would establish a $20 million revolving fund. Money would be available to dam owners who could show that they could not obtain other funds. Currently, no Federal money is available to help repair dams that are not Federally owned. The bill also would provide $2 million over a three-year period for training state dam safety inspectors and professional engineers. It is estimated that ten inspectors from each state could be given a one-week course in the first year. The total cost of the provisions in the McClure bill would be $37 million in FY 1979 and $16.5 million in each of the following two years. The Corps of Engineers has taken no position on the McClure bill, other than to suggest deferral of action until a year's experience under the inspection program has been gained.

Another bill, sponsored by Sen. Jennings Randolph (D-W.Va.), Chairman of the Senate Committee on Environment and Public Works, passed the Senate along with the McClure bill. This proposed legislation is designed to clear up some problems which, although they have not hampered the inspection program so far, might impede it in the future. The first problem is that of right of entry. The Randolph bill would amend the 1972 dam safety act to make it clear that the Corps and its agents (such as architect/engineer firms working on contract) have the right to enter private property to inspect a dam and obtain information relevant to determining its safety. So far, there have been only one or two cases in which inspectors have been refused access to dams. Under current law, Corps inspectors obtain access through the legal rights of the states. The Randolph bill would also assure that architect/engineer firms would not be held liable for damages if a dam they did not find unsafe later failed. Some firms, both large and small, have refused to bid on contracts to inspect dams because they feared that they would be taking on liability. Enough other qualified firms have been w..ling to do the work, however, that the program has not been slowed significantly because of the liability question.

The large and growing number of privately owned dams in the US makes a comprehensive dam safety program necessary. It was a need long neglected, until recent dam failures underscored its importance. Now the task is begun—with initial inspections of the most important dams by the Corps, its contractors, and the states. Already, with under ten percent of the dams inspected, Corps officials say that the program has saved lives: unsafe dams have been found and emergency measures taken that have prevented imminent dam failures. The next step is to see that effective programs of continuing surveillance come into existence. While the Federal government may take steps to encourage the development of adequate on-going programs, the responsibility lies in the hands of the states. ■

When the Kelly Barnes dam collapsed, flood waters tossed automobiles and trucks about like toys.

Events, Deeds & Deliberations



A replica of the deep sea submersible Alvin *on display at Planet Ocean.* (Photo by the author.)

Planet Ocean

by **John C. Fine**

You've probably never flown purposely through an ocean hurricane, explored the marine depths in a deep-sea submersible, touched an iceberg, or stood on the bridge of a ship rolling in wild seas. Risking the perils of the earth's vast oceans is beyond the ken of most men. Many, however, have stood on the beach and marvelled at the mysteries beyond the breaking surf.

It is to help men understand that the International Oceanographic Foundation (IOF) is developing Planet Ocean, on Virginia Key across from downtown Miami. Planet Ocean is built around several theme exhibits which depict the physical ocean environment, the birth of the oceans, their importance as the source of life, their climatic and physical phenomena; and man's relationships with the sea—his exploration, exploitation and pollution thereof. Finally, Planet Ocean dwells on the seas as a legacy for future generations of this planet.

The viability of Planet Ocean is due in large measure to the foresight of Dr. F.G. Walton Smith. Formerly Dean of the Rosenstiel School of Marine and Atmospheric Science at the University of Miami, Smith founded the IOF in 1953. It has now grown to a membership of 70,000, from 105 nations. Planet Ocean is its most ambitious undertaking to date.

Exhibits already open to the public include the 7½-ton Perry-Link submarine, on long-term loan from the Smithsonian Institution. This sub was the first deep-sea submersible to descend to over 700 feet and "lockout" divers to permit them to work in the depths. Visitors are allowed inside.

An 11-ton wellhead completion device, looking like an iron Christmas tree, illustrates the equipment used in man's deep sea explorations for oil. A scale model of the *Glomar Challenger,* with an authentic bit from her drilling rig, will help recall this special ship's role in deep ocean coring, exploration of the mid-Atlantic ridge, and ultimate proof of the Continental Drift Theory. A life size replica of *Alvin,* the sub that participated in the recovery of the atomic weapon lost off the coast of Spain in 1966, is also on exhibit. The real *Alvin* is still operating out of the Woods Hole Oceanographic Institute and has logged dives to 9,000 feet.

Ship's Morse Code telegraphs, models of deep-sea divers in both modern and historical underwater garb, ship's models, and an artificial iceberg all add to the aura of Planet Ocean.

Physical exhibits about the oceans, however, are just one aspect of Planet Ocean, whose building also serves as world headquarters for the IOF and editorial offices for the Foundation's *Sea Frontiers* and other publications. In addition to more than 100 present or planned exhibits, there are two major and three mini-theaters which present continuous films and animated slide shows. The 35mm, wide screen Academy Award nominee *The Unlikely Planet* is shown in its own theater. This film takes the viewer on an exciting spaceship voyage through the

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Mr. Fine is a New York State attorney-at-law.

inhospitable planets of our solar system in search of life—finally unfolding the story of Earth's oceans as the wellspring of life.

Dr. Smith's goal is one of understanding, and he is disdainful of those who attempt to panic the general public into a hysterical fear of the death of the oceans.

"Those who ten years ago predicted the oceans would be dead in a decade," he asserts, "were dead wrong. This is not to say that we don't have to be concerned about pollution of the oceans and maintain our vigilance, but most of those who proclaimed the oceans dying were not scientists. They do some good in alerting the public to the problems of pollution, but they also do great harm.

"We cannot be hysterical about the approach we take in analyzing the problems of pollution and multiple ocean uses. A scientist makes rational analysis of the facts, presents them objectively, and then makes decisions based on those facts."

It is on this kind of firm analytical basis that Smith has grounded Planet Ocean—its scientific and educational message made more palatable through the showmanship of animation and modernistic teaching models. ■

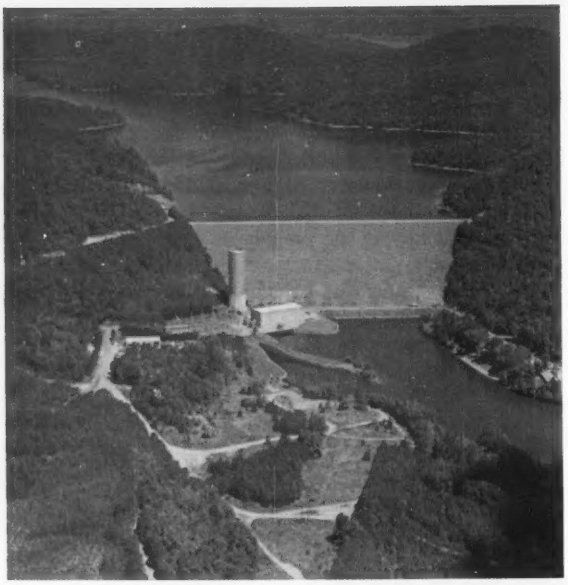
Corps Lake Improved

Lake Ouachita, Arkansas, is a good fishing lake. Years ago, it was an excellent fishing lake. After the completion of Blakely Mountain Dam (which impounds Ouachita) in 1953, anglers enjoyed a brief eight-year period of high fishing success. However, as inundated trees decomposed and contours eroded, the fish lacked adequate shelter and nutrients and angling success fell off drastically.

In response to interest shown by the Arkansas Bass Association in improving fishing on the lake, a four-man crew spent nearly a month in late 1977 constructing more than 120 artificial fish shelters around the lakeshore. Uprooted trees were collected and placed in groups of about five each, then tied together, weighted with concrete and sunk in coves and bays. The clumps were located in 5-20 feet of water with a short portion of the trunks exposed on shore.

In the absence of adequate cover, the artificial fish shelters improve spawning conditions for crappie and black

Lake Ouachita, Arkansas



bass. They also provide shelter for other sunfish species, and attract the smaller fish that game species feed on. To encourage use of these areas by fishermen, maps showing the location of fish shelters—"structure," in the idiom of bass anglers—are available.

Construction of fish shelters is only a part of the continuing wildlife habitat enhancement program on Lake Ouachita. Additional fish shelters will be placed on the lake annually. To improve shoreline fishing conditions, areas near heavily used shoreline will be a primary target.

The fish shelter program was conducted under the auspices of the Vicksburg District, U.S. Army Corps of Engineers. ■

Phosphorous Leaching Studied

Scientists at Oklahoma State University are studying how different types of soil affect the amount of phosphorous that drains into lakes and streams, under a cooperative agreement with the U.S. Department of Agriculture.

Researchers know that excessive soluble phosphorus, a major plant nutrient, contributes to the aging of lakes and streams. The phosphorus helps make the water rich in nutrient but low in oxygen. This, in turn, leads to pollution.

With up to $26,300 provided by USDA's Science and Education Administration, the researchers will study phosphorus concentrations in soils as compared with concentrations in runoff water and sediments in lakes and streams. They will make the tests on four sites in Texas and Oklahoma where land is subjected to differing uses.

The overall objective is to improve an already available mathematical modelling system that is used to predict phosphorous concentrations in runoff water. ■

Bookshelf

Aquaculture in the United States: Constraints and Opportunities looks at U.S. aquaculture from all angles—production, science, technology, economics, business, law, and administration. It finds that "constraints on orderly development of aquaculture tend to be political and administrative, rather than scientific and technological." The report, published by a committee of the National Research Council, recommends policy changes and research that would facilitate the development of the aquaculture industry. Available from the National Academy of Sciences, 2101 Constitution Ave., Washington, DC 20418. ■

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Aquacultural Engineering, by Frederick W. Wheaton, focuses on the technical problems of producing food and fiber from aquatic resources. The first part of the book describes the physical and biological aspects of the environment that affect aquatic life and so are important variables in the design of aquaculture projects. The book's second part emphasizes engineering considerations in cultured (as opposed to fisheries) acquaculture. Dr. Wheaton is an Associate Professor of Agricultural Engineering at the University of Maryland. Intended for biologists, hatchery managers, aquaculturists, and students as well as engineers, the book is available from Wiley-Interscience, 605 Third Ave., New York, NY 10016. ■

Tuning the Green Machine, by the Institute for Environmental Education and the Association of New Jersey Environmental Commissions, is intended to aid citizens in making responsible decisions that affect their environment. In 320 pages, the book presents an integrated view of environmental systems, the nature and sources of pollution, the legal and technical means for abating pollution, health and the environment, land use, and energy and its conservation. Available from the Association of New Jersey Environmental Commissions, 300 Mendham Rd., Rt. 24, Box 157, Mendham, NJ 07945. ■

Water Needs for the Future, edited by Ved P. Nanda, is available from Westview Press, 1898 Flatiron Court, Boulder, Colorado 80301. This volume addresses the legal, political, economic and technological aspects of water policy formulation for the future. Although many of the chapters are, necessarily, of Coloradan problems/solutions, their applications are universal and innovative. ■

Salt Water Purification, by Dr. K. S. Spiegler, is written for the nonspecialist in the field and covers a broad spectrum of various methods of water desalinization now in practice and under development. Major topics explored by the University of California at Berkeley faculty member include economic factors regarding desalting equipment and material, and alternate methods of obtaining an adequate water supply. Available from Plenum Publishing Corp., 227 West 17th St., New York, NY 10011. ■

. . . And the Desert Shall Rejoice, by Arthur Maass and Raymond L. Anderson, examines irrigation communities in southeastern Spain and in the western United States. The authors' investigation covers past and present water resource institutions in selected settlements in a comparative framework, and in terms of how they approach such goals as successful conflict resolution, participation, local control and economic growth. Water distribution policies, for example, may in some cases be based on time (seniority of settlement), and in others on place (position along the stream). Available from the MIT Press, 28 Carleton Street, Cambridge, Mass. 02142. ■

Changes of Command

Major General William R. Wray has been named Director of the new Military Programs Directorate in the Office of the Chief of Engineers, Washington, D.C. General Wray formerly served as the Assistant Chief of Engineers.

Major General Louis W. Prentiss has been assigned as Ohio River Division Engineer. General Prentiss formerly served as Deputy Chief of Staff, Engineer, Headquarters, U.S. Army Europe. He succeeds Brigadier General E. R. Heiberg III, who has been recommended for promotion to the rank of major general. A former North Central Division Engineer, Brigadier General Robert Moore, was also recommended.

Brigadier General William E. Reed was named Assistant Chief of Engineers, Office of the Chief of Engineers, Washington, D.C. General Read previously served as Missouri River Division Engineer with headquarters in Omaha, Nebraska.

Colonel Clyde A. Selleck becomes Missouri River Division Engineer and succeeds General Read.

Colonel Terrence J. Connell will become Portland District Engineer effective in January. He will succeed Colonel Harvey L. Arnold, Jr., whose assignment will be announced later. Colonel Connell was serving as Deputy Director of Army Research on the staff of Deputy Chief of Staff for Research, Development, and Acquisition. ■

Coming Events

"Coastal Structures 1979" conference at Alexandria, Virginia, March 14-16, 1979.

International Water Reuse Symposium at Washington, D.C., March 25-29, 1979.

22nd Annual Conference of the Great Lakes 79 International Association for Great Lakes Research at Rochester, New York, May 1-3, 1979.

Pecora Symposium of the American Water Resources Association at Sioux Falls, South Dakota, June 11-13, 1979.

15th Annual American Water Resources Conference at Las Vegas, Nevada, September 24-28, 1979. ■

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